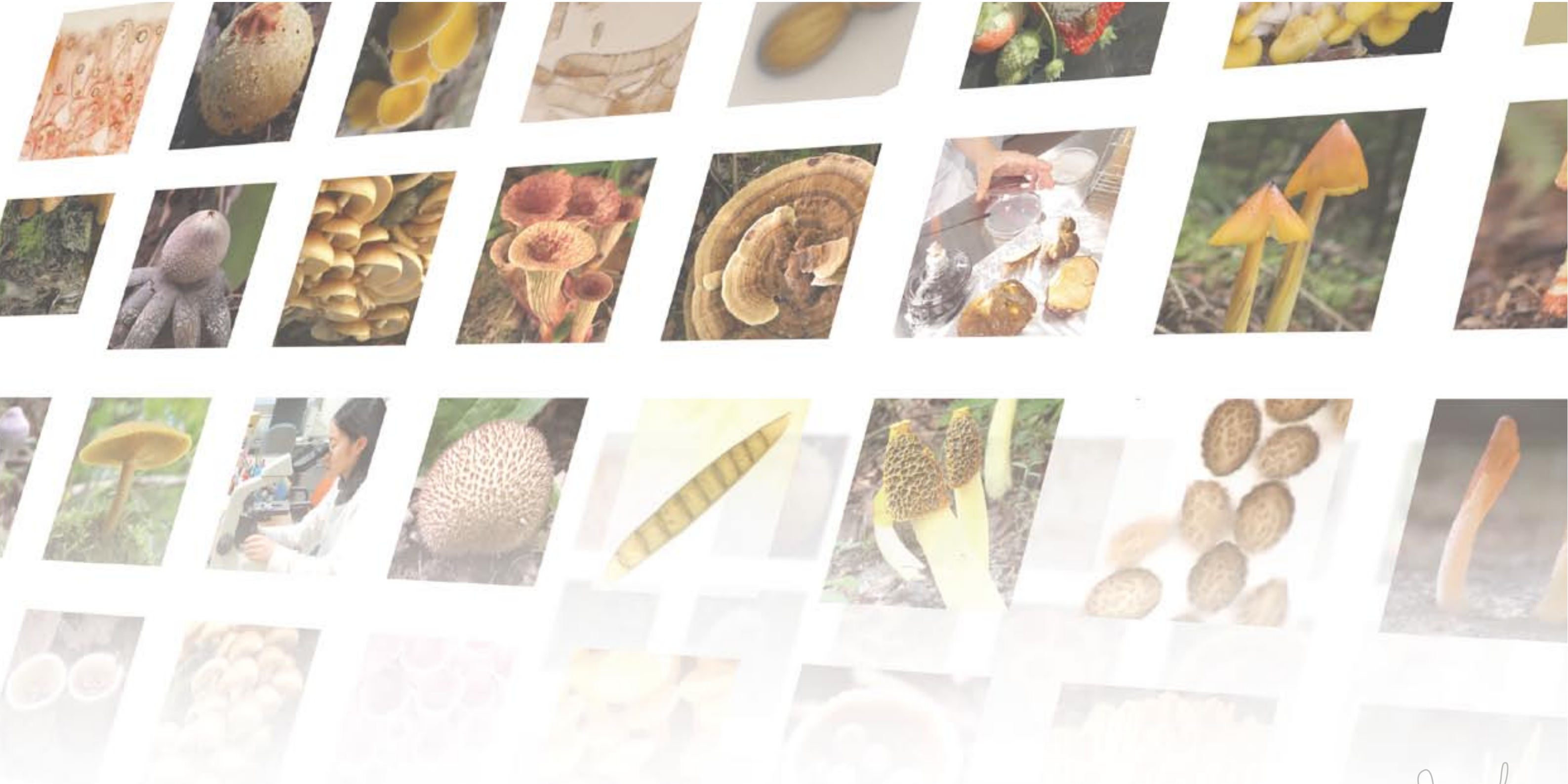
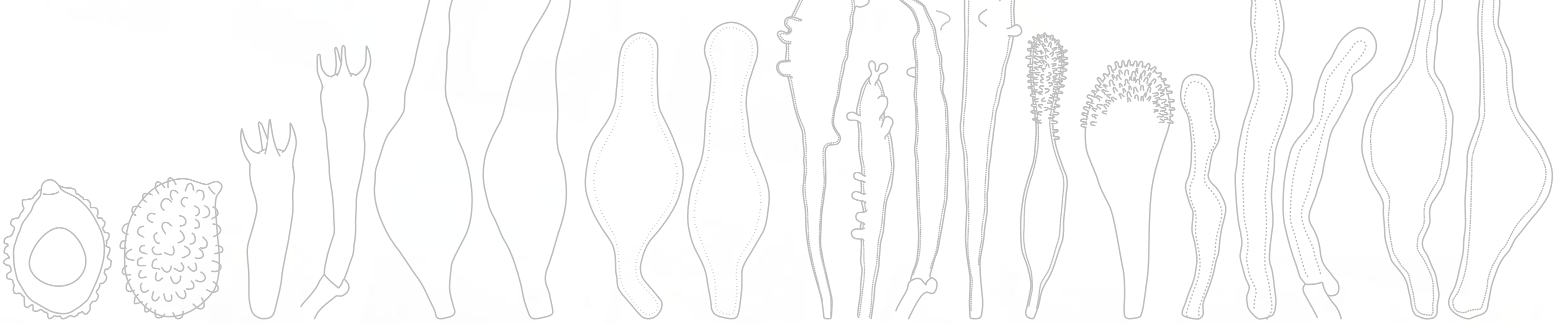
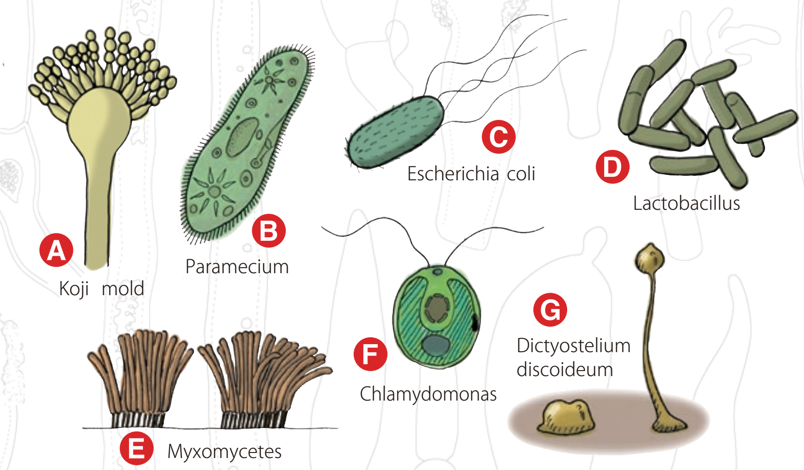


Introduction to THE WORLD OF FUNGI



Let us learn about fungi correctly

What do you think of when you hear the word "fungi"? Many people have misconceptions. So, let us start by understanding correctly what kind of organisms fungi are.



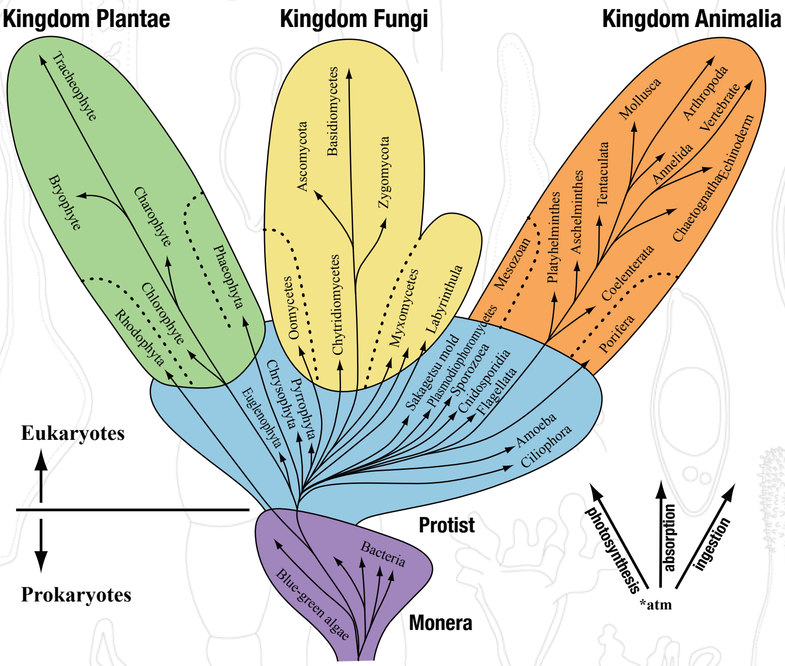
What do you think of when you hear the word "fungi"?

Organisms other than fungi are also included in the figure to your left. Which are fungi?

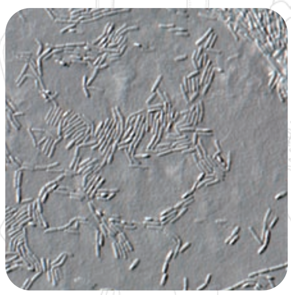
Myxomycetes (E) and Dictyostelium discoideum (G) are considered to be fungi in a broad sense. Although Escherichia coli (Daicho-kin) and Lactobacillus (Nyusankin) have "-kin" in their name, they actually are not fungi (kin-rui). First, let's understand how to define the characteristics of fungi.

Fungi are neither animals nor plants; they are also not bacteria.

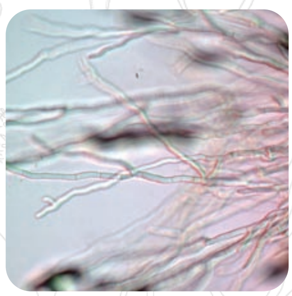
When all the organisms were classified as either animals or plants, fungi were categorized as plants. However, they were later recognized to belong to an entirely different kingdom: Plants produce nutrients through photosynthesis and animals derive nutrients through eating these plants and other animals. On the other hand, fungi derive nutrients in other ways, such as through degradation of both animal and plant remains (saprophytes). Hence, they contribute to the maintenance of ecosystem balance and nutrient and carbon cycling and are now recognized to form a kingdom distinct from both animals and plants. As bacterial cells do not contain a nucleus surrounded by a nuclear membrane, they are considerably different from eukaryotes such as animals, plants, and fungi. Today, fungi are considered to be eukaryotic and often produce mycelia, a basic filamentous structure; further, they have no photosynthetic functions and contain a cell wall mainly composed of chitin and chitosan. Moreover, they mainly reproduce via sporulation.



When the five kingdom system was proposed by Whittaker (1969), fungi was distinguished from plants and animals on the basis of nutrition mode. Fungi absorb nutrition by degrading materials while plants produce their nutrition by photosynthesis and animals digests their nutrients internally by eating from their mouths (ingestion). The three members of the kingdoms represented producers (plants), consumers (animals), and decomposers (fungi), respectively in nature. The concept was largely based on the ecological nature of the organisms. The system was cited in the biology textbooks for decades, but it does not explain the phylogeny. Now, fungi are known to be closer to animals than plants (see the figure in page 7).



Bacterial cells are smaller than fungal cells and have no nuclei.



Both molds and mushrooms consist of mycelia (filamentous cells linked together).

Fungi are neither animals nor plants, and neither are they bacteria.

This is why fungi are important

All animals and plants cannot live without fungi. This may seem like exaggeration, but recent research has shown that even plants that acquire nutrients from photosynthesis require fungi. In addition, especially for the Japanese people, they are essential life partners. Let's think about the relationships between our lives and fungi.

Fungi are our life partners

Food

Edible mushrooms, bread, soy sauce, and sake: These cannot be separated from the lives of the Japanese. Soy sauce and miso are prepared through fermentation by the koji mold (Aspergillus oryzae). Seasonings, such as sake and mirin and dried bonito are also prepared using fungi. Bread, wine, and beer are all prepared through fermentation by yeast. Fungi are involved in the production of various fermented foods, thereby adding value to our lives.

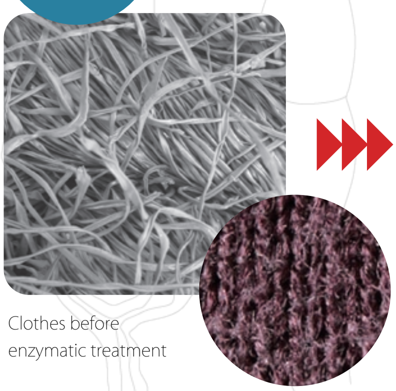
Living

Medicinal supplies and ornaments: The very first antibiotic (drugs to suppress bacterial growth) was penicillin, which was produced by a type of mold. A variety of physiologically active substances are also known to be produced by fungi; they are indeed an important biological resource for medicinal products. Moreover, pigments from fungi can be used as dyes (e.g., mushroom dye), and they are often used in arts, thereby enriching our lives.

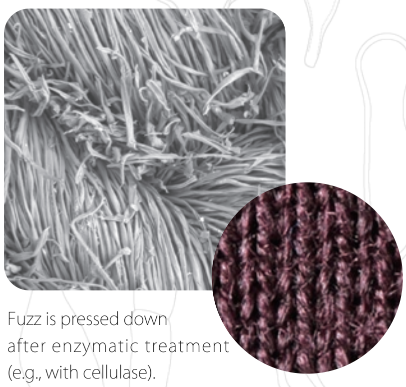
Kamakura-bori is processed using the spores of black mold.

Substances made by fungi can be used in the manufacture of drugs.

Cloth



Clothes before enzymatic treatment



Fuzz is pressed down after enzymatic treatment (e.g., with cellulase).

Using fungi to treat material: You may wonder whether clothes and fungi are related. As the enzymes produced by fungi degrade a variety of substances, they are used to remove stains and process fibers. For instance, when denim is processed by an enzyme called cellulase, it creates a stone-washed texture where the surface is partially broken. An enzyme lipase, which degrades oil, is also used in detergent.

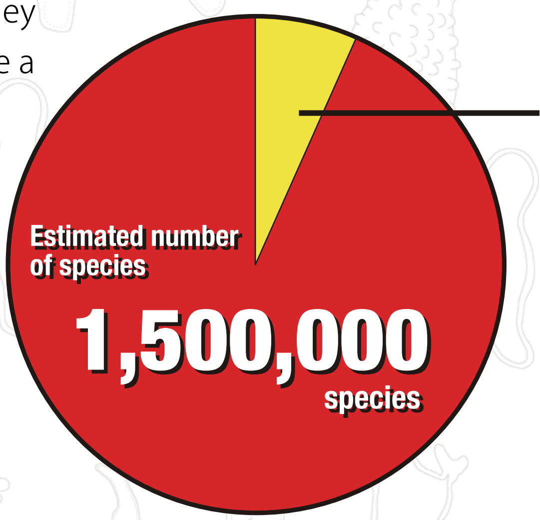
Representative blue mold that produces penicillin. *Penicillium chrysogenum.*

Nematode-eating fungi. These are types of molds that trap and eat nematodes. The image shows *Arthrobotrys.*

A laboulbeniomycete (*Rickia* sp.) parasitize the surface of a tick's stomach. They are special fungi evolved as insect parasites.

Striking Diversity

Fungi live not above ground, but also grow below ground in the soil, as well as in inland water environments,and even oceans. They all show a striking diversity in morphology and ecology. Let's have a look at their diversity.



An example of a beautiful mushroom, *Amanita caesareoides*. This mushroom produces mycorrhizae with Fagaceae plants. This is an edible mushroom. Please do not confuse it with a poisonous mushroom with similar appearance, *Amanita muscaria.*

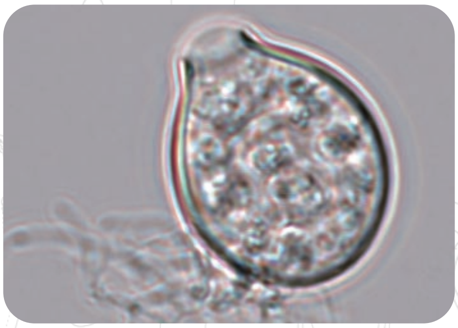
Cordyceps nutans is a relatively well-studied *Ophiocordyceps sinensis*, a type of mushroom produced on insects.

Leratiomyces erythrocephalus, found in New Zealand, has a stem but no gills. It is partially similar in appearance to fungi that fruit belowground (hypogeoous), and is considered to be an inter-mediate form between hypogeous fungi and epigeous (aboveground) mushrooms.

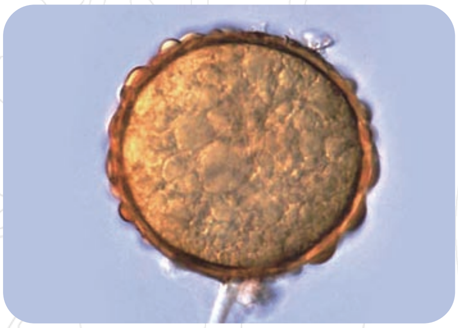
Exobasidium gracile causes swollen leaves in *Sasanqua camellia* called Sasanqua mochi-byo. This plant pathogen causes the deformation and withering of plants.

Molds on mushroom. Some of the molds parasitize mushrooms. The image shows a type of *Spinellus*, parasitizing a mushroom.

A representative of ocean fungus, *Corollospora*. Spores have thorns and fluttering attachments, which make it easier to capture nutrients.



Batrachochytrium dendrobatidis is an amphibian pathogen, which has caused the extinction of several animal species. Zoospores (running spores) are formed within a pot-like structure.



Glomus species can form arbuscular mycorrhiza (a type of beneficial fungal and plant interaction). The fungus provides the plant with phosphorous and nitrogen from the soil i in return for photosynthesis products.

Known Species

Approximately

97,000

species

So far, known fungi are consisted of around 97,000 species. However, estimated number of fungi is said to be around 1,500,000 species, which means that fungi are the second largest guild following insects on earth. This is significantly larger than 270,000 and 44,000 of tracheophytes and vertebrates, respectively.

Luminescent mushroom *Mycena chlorophos*. Some mushrooms are known to illuminate. However, the clear reasons remain uncertain.

Auricularia auricula-judae, which is written as "a ear of tree", also belongs to fungi. There are various mushrooms that have jelly-like fungal fruiting body.

Cyttaria is a rare fungus only parasitize on Nothofagaceae in the southern hemisphere, such as Australia and New Zealand

A type of *Hysterangium*, *Hysterangium* sp. Among mushrooms, some of them have adapted to the underground life, like this species.

Bloom-like branched mushroom, *Ramaria* sp. A variety of types are known to belong to this species.

Calvatia craniiformis has the dumpling-like funny structure; this species evolved from a mushroom with a cap.

Polyporaceae is a general term to describe bracket mushrooms. Most of them are wood-decay (saprophytic) fungi.

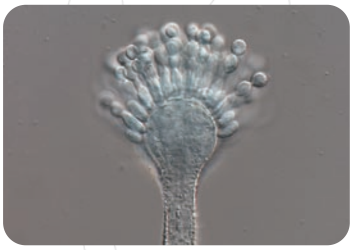
Fungi are diverse organisms; most of them have not yet been discovered.

Familiar fungi that appear in textbooks

Koji mold *Aspergillus oryzae*

The surface of koji is closely packed with koji mold. Take a small amount, loosen as shown below on this page, and observe.

How to obtain: The easiest way is to purchase commercially available koji. It may be dry and store. **How to observe:** Observe using a loupe and stereoscopic microscope. Pick a small amount using a dissecting needle or tweezers. **Important morphological:** A swollen structure called vesicle contains cells that produce spores, and from here, spores are continuously produced as if they are pushed out. **Characteristics observed:** Koji are important as they are used to produce miso, soy sauce, and sake. They produce a variety of enzymes that can be applied in many fields. Moreover, this is the first fungus whose genome was analyzed.

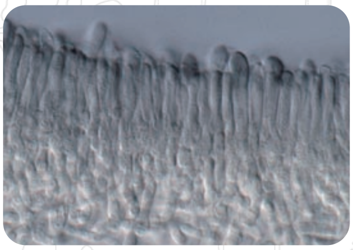


Microscopic image of koji mold

Lentinula edodes

Fibers that you see when you tear up are the bundle of hyphae.

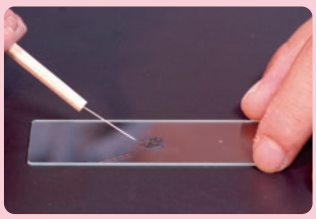
How to obtain: The easiest way is to purchase commercially available shiitake-mushroom at a supermarket. **How to observe:** Vertically slice the gill of mushroom into thin strips, prepare a specimen for microscopic observation, and microscopically observe spores and basidia. You may press down a part of the gill for observation. Commercially available mushrooms may remain premature and are therefore not ideal for observation by beginners (beginners are recommended to use Russulaceae). **Important morphological:** It produces four colorless spores on a long a narrow basidium. **Characteristics observed:** Japan was the first to industrially produce this mushroom. It has value as food and has a historical importance. If you tear a part of the mushroom and prepare a specimen for observation, you may observe that mushrooms are indeed composed of hyphae.



If you slice the gill and observe, you will see basidia and spores at the edge.

This is how to observe

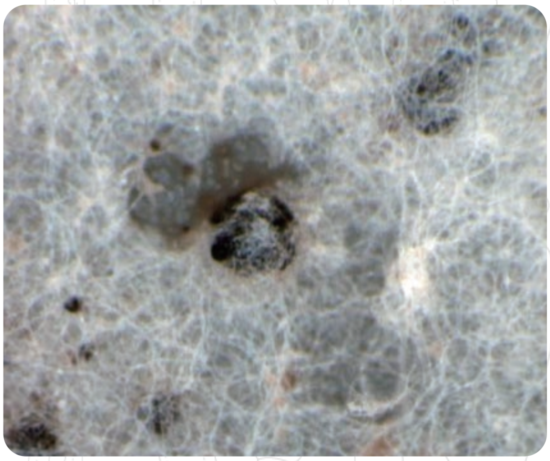
Depending on the samples, you may omit some of the procedures. For example, a drop of yeast solution can easily be observed by directly placing it on a glass slide. In the case of mushrooms, samples may need to be pressed down. Therefore, an appropriate observation method depends on the characteristics of each sample.



Place a droplet of water on a slide glass. Take a small amount of sample (material to observe) using a dissecting needle or tweezers.

Fungi are described in textbooks for junior high school and senior high school. However, few seem to accurately describe the shape of fungi. Let us introduce some of the familiar fungi that appear in textbooks.

Neurospora crassa



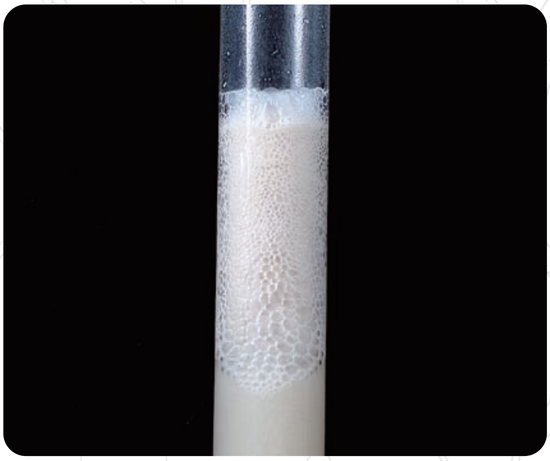
Perithecium of *Neurospora crassa*. A sac called ascus is found in the black grain structure.

How to obtain: Request and purchase from a strain collection organization. Unfortunately, if you are not an expert, they will be difficult to isolate from nature. **How to observe:** Cultivate on an appropriate medium for the fungal fruiting body (called perithecium) to form. Take the perithecium, prepare the specimen for microscopic observation, and observe. **Important morphological:** Eight spores are formed within the ascus formed in perithecia. **Characteristics observed:** As Neurospora crassa is fast growing and stably forms a perithecium, it has been used in genetic studies for many years. Beadle and Tatum used this fungus to proposed the one gene-one enzyme hypothesis.

Ascus of *Neurospora crassa*. Eight spores are present within.

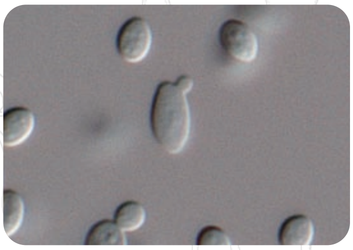
They are transparent at first but darken as they ripen.

Saccharomyces cerevisiae



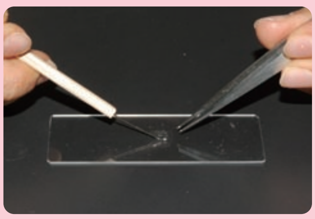
Carbon dioxide foam produced through the activity of bread yeast.

How to obtain: Easiest is to purchase as dry yeast at a supermarket (frozen and dried bread yeast). **How to observe:** Dissolve in approximately 5% sugar water and warm for 1–2 h at room temperature (you may warm it up to 37°C). Later, prepare a specimen for microscopic observation and observe with an optical microscope. **Important morphological:** They form unicellular bodies of spherical-oval shapes. They form daughter cells (budding) from a part of the cell as if it germinates and proliferates. **Characteristics observed:** They are used in the fermentation of Japanese sake, beer, wine, and bread. In addition to alcohol production during fermentation, they also produce carbon dioxide, a characteristic that is utilized in the production of bread and beer. Better strains are being continuously isolated in nature.

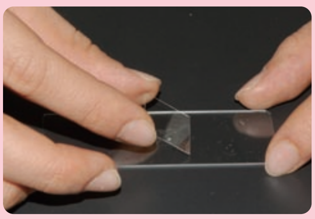


Budding yeast cells.

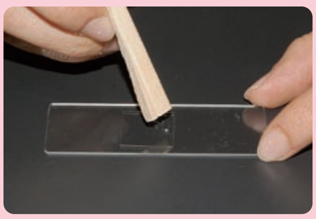
Fungi are important in various fields such as biology and applied science.



Loosen a sample using a dissecting needle and tweezers (or two dissecting needles).



Place a cover glass carefully to prevent trapping air bubbles.



Press down the cover glass using a tool such as the shaft of a dissecting needle.

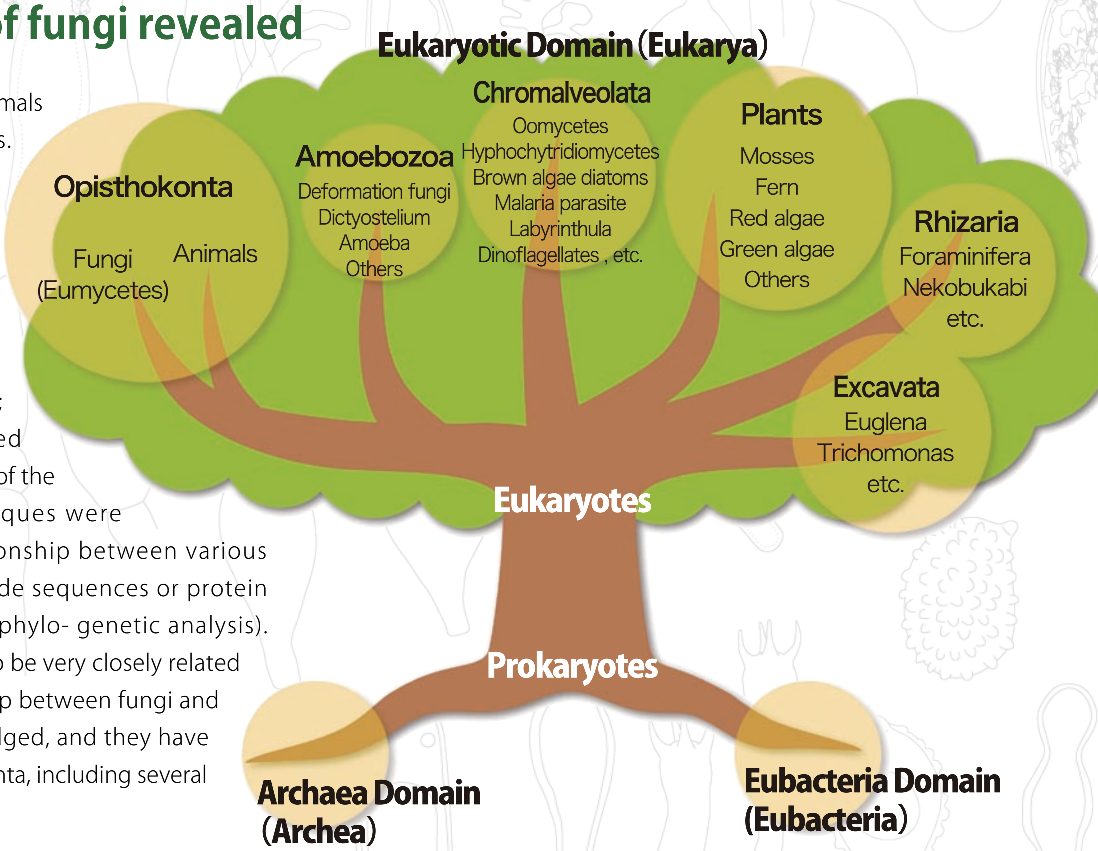
Place on a microscope and observe.

The latest fungi news and trivia

The science of fungi progresses every day. Here we provide the recent important news.

Biological position of fungi revealed

Fungi neither actively move like animals nor are they autotrophic like plants. Then, do they share a common ancestor with some organisms? Until the middle of the 20th century, fungi were considered as lower plants without chlorophyll. Later, it gradually became apparent that fungi are distinct from plants; however, their ancestors remained uncertain for many years. At the end of the 20th century, a variety of techniques were developed to elucidate the relationship between various organisms based on DNA nucleotide sequences or protein amino acid sequences (molecular phylo- genetic analysis). Consequently, fungi were revealed to be very closely related to animals! Currently, the relationship between fungi and animals has been widely acknowledged, and they have been grouped together as Opisthokonta, including several other unicellular organisms.



Are the scientific names of fungi going to change greatly? A note on nomenclature revision rules

Most of the fungi reproduce by two reproductive methods: asexual or sexual. In most cases, the former are recognized as molds, whereas the latter are considered as mushrooms. However, some mushrooms reproduce like molds. As they are morphologically distinct from each other, when they are in the period of mold, they have been considered as "imperfect fungi" and given different scientific names from the mushroom phase. Fungi are the only organisms to be given two distinct scientific names.

This is an exceptional case in the nomenclature of organisms. Today, organisms can be linked based on molecular information; hence, it was decided to give only one name to these fungi ("International Code of Nomenclature for algae, fungi, and plants", 2011). The rule concerning the scientific names of fungi was implemented on January 1, 2013; however, the sorting and arranging of actual names has taken longer than expected. Currently, discussion is ongoing to decide which name to select in each group of fungi.

Radiation and mushrooms

Fungi are the representatives of the most diverse organisms in the forest ecosystem. Numerous spores are present in soils, and various types of mycelia have been established. Mycelia degrade not only fallen leaves and trees but also form relationships with living plants through roots by constructing symbiotic systems such as mycorrhiza, which exchange nutrients. In such manner, mycelia are tangled together in complex ways in soil to form networks.

Because most fungi exist in soil, their role in cycling of carbon and nutrients in the soil is enormous. In particular, many types of mushrooms absorb a variety of substances through mycelia which are accumulated in fungal fruiting body. Radiation is not an exception. Many mushrooms accumulate higher concentration of radioactive cesium than plants and animals.

After the incident at the nuclear power plant associated with the Great East Japan earthquake, wild and log-grown outdoor mushrooms at various locations around eastern Japan were reported to contain relatively high concentrations of radioactive cesium. However, after some investigation, it was revealed that not all the mushrooms accumulate radioactive cesium. Cesium concentration significantly varies depending on the types of mushrooms and their growth environment. Therefore, it is highly erroneous to believe that all the mushrooms are dangerous.

In contrast, continuous monitoring of cesium concentration in mushrooms can reveal the natural circulation of cesium. Several research groups of the Mycological Society of Japan are planning to monitor cesium concentration in mushrooms over the next several decades as a part of fungal research.

Germanium semiconductor detector

Schizophyllum commune

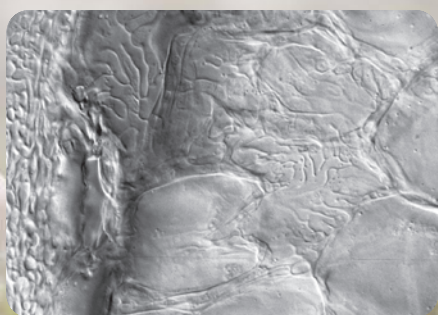
Morchella esculenta

The roles of fungi, more than degradation

Where do plants obtain necessary water, nitrogen, and minerals to live? The efficiency at which plants obtain these from the soil is doubled when facilitated by symbiotic mycorrhiza. The relationship of plants with fungi begins from germination and continues through blooming until the completion of their lives; however, during the process of nutrient absorption from soil, their symbiotic relationship with "mycorrhizal fungi" is essential. In the rich natural environment of Japan, the role of universal mycorrhizal fungi tends to be ignored. However, if mycorrhizal fungi disappear, forests and meadows will also disappear. Forest trees, such as pine trees and oaks are in symbiotic relationships with mycorrhizal fungi (e.g., many Basidiomycota and Ascomycota) and various other plants symbiotically live with arbuscular mycorrhizal fungi (Glomeromycota). Some of the plants, such as certain orchids and Monotropa hypopitys, became chlorophyll-free plants and therefore completely dependent on mycorrhizal fungi. To begin with, terrestrial plants are considered to have originated from the symbiosis with mycorrhizal fungi near shores approximately 400 million years ago. The mycelium of mycorrhizal fungi is the major microbial biomass in soil; therefore, they are also considered to play a key role in the global carbon cycle. Several thousand types of mycorrhizal fungi are thought to be distributed in Japan; however, their details remain uncertain. Treasures of forests such as matsutake, Lyophyllum shimeji, and truffles are also mycorrhizal fungi.

A type of *Russula*, a representative mycorrhizal fungus

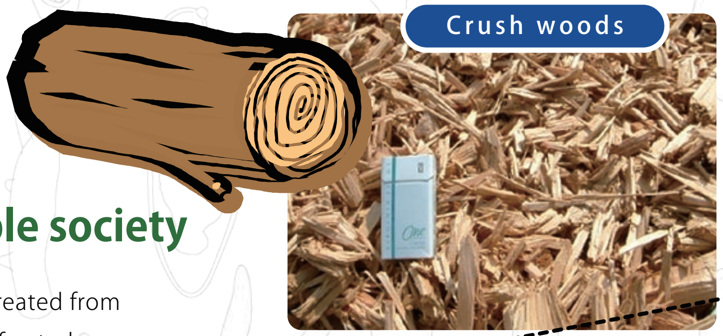
Ectotrophic mycorrhiza formed on the root of pine tree



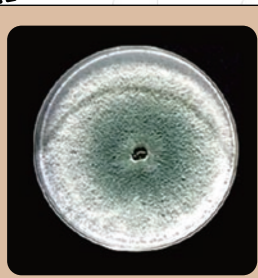
Surface structure of mycorrhiza. Mycelia are deformed and cover root cells.

Secrets of fungi have been revealed one by one! Let's update our knowledge too!

From petroleum to biomass: Fungi which support sustainable society



Various "materials" that support our lives have been created from petroleum products. However, to mitigate the shortage of petroleum resources and reduce the environmental burden, we need to produce various materials using plantderived sustainable resources. Biomass such as wood is a representative sustainable resource. A variety of fungi are involved in the processes, including saccharification and fermentation, which are necessary for the production of such materials.



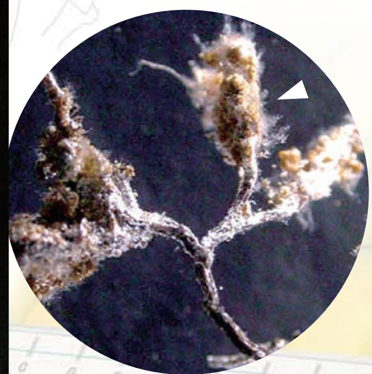
Trichoderma reesei, a representative cellulose-degrading enzyme-producing fungus

Talaromyces cellulolyticus, domestic cellulose-degrading enzyme-producing fungus

For the artificial cultivation of matsutake

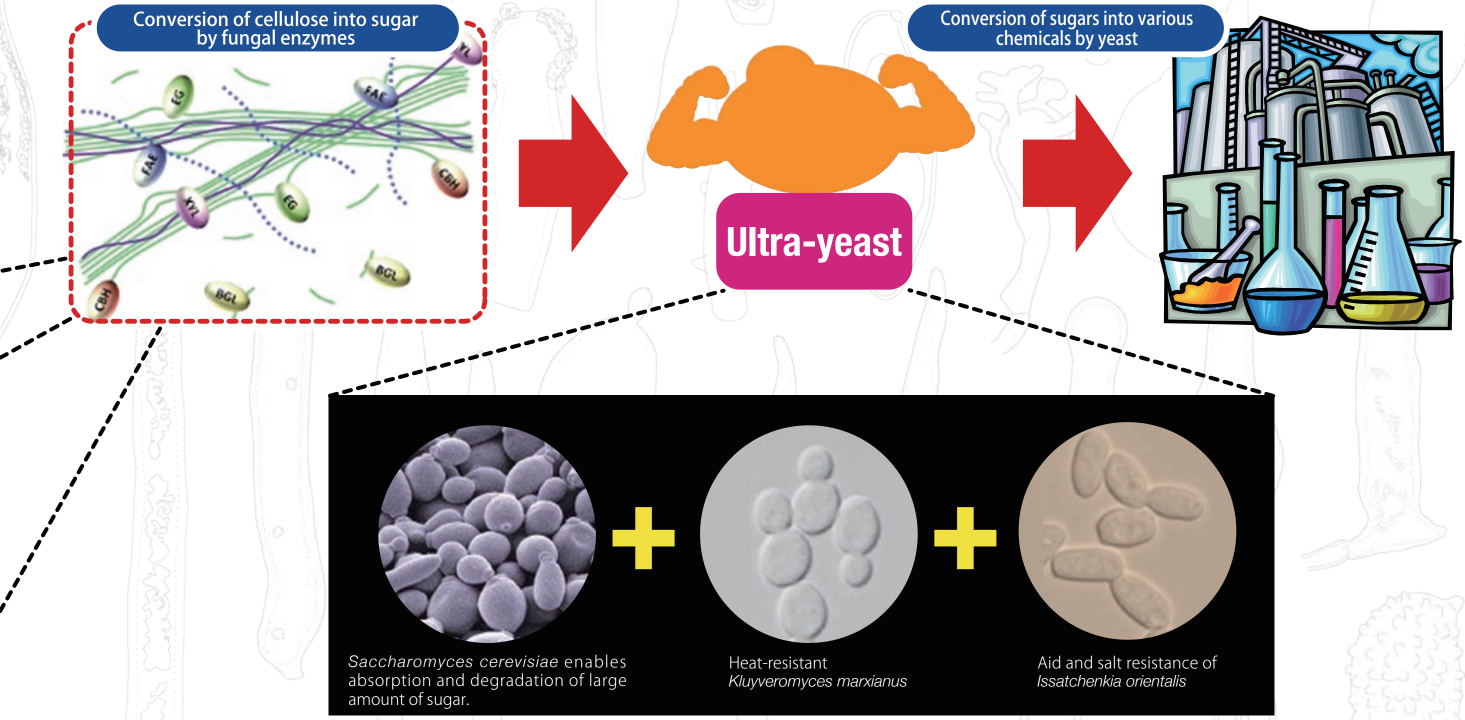
Matsutake are difficult to cultivate and are therefore sought after and traded at a high price. Domestic production of matsutake has declined drastically, and many imported mushroom have been widely traded. Thus, a variety of studies have been in progress for its cultivation. A potential difficulty in cultivation is that matsutake is a mycorrhizal mushroom living symbiotically with the roots of plants such as Japanese red pine in forest areas. Therefore, there are various ongoing projects to facilitate the growth of matsutake by developing the forest environment suitable for the growth the mushroom. In addition, to artificially introduce matsutake fungi into a forest area, matsutake-fungi have been inoculated to the roots of Japanese red pine that have been antiseptically germinated within a sealed container. The pine seedlings were then planted outdoors for the establishment and propagation of fungi in the field. In contrast, some studies are also ongoing based on the pure culture of matsutake, rather than using the symbiotic system with plant roots. The cultivation of Lyophyllum shimeji, also a type of mycorrhizal mushroom, has already achieved success.

The seedling of Japanese red pine grows symbiotically with matsutake.



Matsutake mycorrhiza formed on the seedling of Japanese red pine. The arrow indicates the mycelia of matsutake covering the root surface.

Fungi are important biological resources which support our future. Here are some applications using these fungi.



Institutions that archive fungal stock that meet the need for fungi to be a biological and genetic resource

Fungi are already essential within our lives; however, they also form biological and genetic resources with the future potential to be used as new materials in the fields of medicine and biotechnology. Organizations that mainly collect microbes such as fungi as biological and genetic resources and store the live strains using on freezing and drying methods are called “strain conservation organizations” (culture collection or bio-resource centers). Academia and corporates can use the various stored cultivated strains for education and research. In contrast, not all fungal strains can be easily cultivated, and some strains, such as mycorrhizal fungi and other symbiotic fungi, are difficult to isolate or cultivate. Strain conservation organizations are also actively involved in various research areas, such as the isolation or development of fungi, thereby contributing to the use of fungal resources.


Isolation of wild mushroom (*Sarcomyxa serotina*).


Fungal strains cultivated and stored in test tubes.


Liquid nitrogen tanks and cryopreserved fungal strains.

Fungi are our important partners that support our lives, and they are also important resources. The wise and sustainable use of fungi is therefore imperative.

About the Mycological Society of Japan

The Mycological Society of Japan was established in February 1956, aiming to promote and familiarize academic research involved in fungi. The society is a representative academic organization that widely exchanges research information concerning fungi. We mainly target materials that have traditionally been the focus of fungal researchers (while also focusing on myxomycetes and oomycetes, already known not to be fungi). The society has approximately 1,000 members, consisting of researchers (including students), as well as corporates and fans of fungi.

From the basics to application, we conduct a wide range of scientific studies in the following fields: biology, plant pathology, microbiology, agricultural chemistry, fermentation technology, applied mushroom science, forestry, medical science, pharmacology, and environmental science.

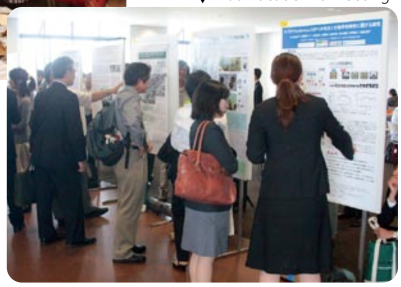
The main activities of the Mycological Society of Japan: An annual general meeting (normally held in spring), fungi observation meetings (normally held in fall), lectures, and symposiums aim for academic exchange between Japanese and international experts along with presentation of research results and information exchange. We also host non-periodic international symposiums and actively cooperate with the International Mycological Association and the Asian Mycological Association. Many researchers from several universities and national research and development institutes along with academic or technology researchers from related companies attend such international meetings, contributing to the promotion of mycology and the sharing of knowledge.

About SNS: Other than the website, the Mycological Society of Japan provides information on SNS. We have accounts on Twitter (@Mycology Japan) and Facebook (the Mycological Society of Japan), and provide a platform for not only the members but also the many people interested in mycology to communicate and interact. These resources can be used to easily obtain the latest information on fungi as well as our activities. Moreover, our SNS account functions as an information hub that introduces the content of fungal research, the activity of mushroom-meetings, and information about books focusing on mushrooms and fungi.

▲ Home page of the Mycological Society of Japan http://www.mycology-jp.org/~msj7/


◀ As a fungi observatory meeting

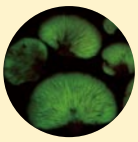
▼ At an academic meeting



Do you know? 100 selections of Japanese fungi

In 2009, we established "100 selections of Japanese fungi" by selecting 100 species of fungi that are closely linked to the lives of Japanese people based on various aspects, including basics and application, nature, and culture. Shiitake (a mushroom whose industrial production was first successful in Japan) and koji mold (essential for the production of sake, soy sauce, and miso) are all important fungi that support the lives of Japanese people or are closely linked to the nature and culture of Japan. How many of them do you know? To know, please access the following link: http://www.mycologyjp. org/~msj7/WL_information_J/100.html



Invitation Guide

Anyone who is interested in fungi and pseudomycetes such as mushroom, fungi, yeast,or myxomycets are welcome to join. If you wish to become a member, please read the society regulations, download the application form, fill in the necessary information, and submit the form to the executive office. (E-mail attachments, fax, or mail)

Membership: 11,000 yen
Student Membership: 5,500 yen (50% of Member)
Lifelong Membership: 110,000 yen
(10 times of the annual cost of member)
Supporting Membership: 50,000 yen per share (more than one share)

If you become a member: You will receive academic journals (six English journals, two Japanese journals, and four newsletters per year) as well as other free or non-free publications. You may attend meetings, fungi observatory meetings, and other events such as gatherings. You may present at meetings.

Publication: Mycological Society of Japan

Text and Pictures provided by・Jyunichi Peter Abe・Shigeki Inaba・Takamichi Orihara・Hisayasu Kobayashi・Ami Shigemori・Kozue Saotome・Yuichi Taneyama・Eiji Tanaka・Yousuke Degawa・Kentaro Hosaka・Takeshi Hosoya・Tamotsu Hoshino・Akiyoshi Yamada

Please contact the Mycological Society of Japan
c/o National Institute of Advanced Industrial Science and Technology, Chugoku,
3-11-32, Kagamiyama, Higashi-Hiroshima 739-0046 Japan
secretary-general@mycology-jp.org