Teaching iThink Biology in Your Classroom

A Guide to Teaching The Kingdom of Fungi chapter

iThink Biology is different from the types of science textbooks we are familiar within India. The content, organization and features of the e-book have been developed with different objectives in mind. We hope that the chapter-wise guides prepared by the iThink Biology team will help a teacher make the best use of the resources in their learning spaces. The following text is a guide to teaching 'The Kingdom of Fungi' chapter. Please read through the section on how to read iThink Biology before using this resource.

Table of contents **(to be added in MS word format)**

Introductory notes

- The book has been written in an informal and conversational style of English and important or difficult concepts have been linked to the glossary or elaborated in detail within the text.
- The book is hosted on a website, so the reader will require a computer, mobile or tablet to access it. An internet connection will be required to access the different pages of the website, as well as the different interactive features of the book such as weblinks, glossary terms, video interviews, and downloadable research papers.
- Several exercises in the book may require students to step out of their classroom and observe their surroundings, such as a city area, water bodies or garden. The possibility of such an engagement can be important to meet the learning objectives of the book.

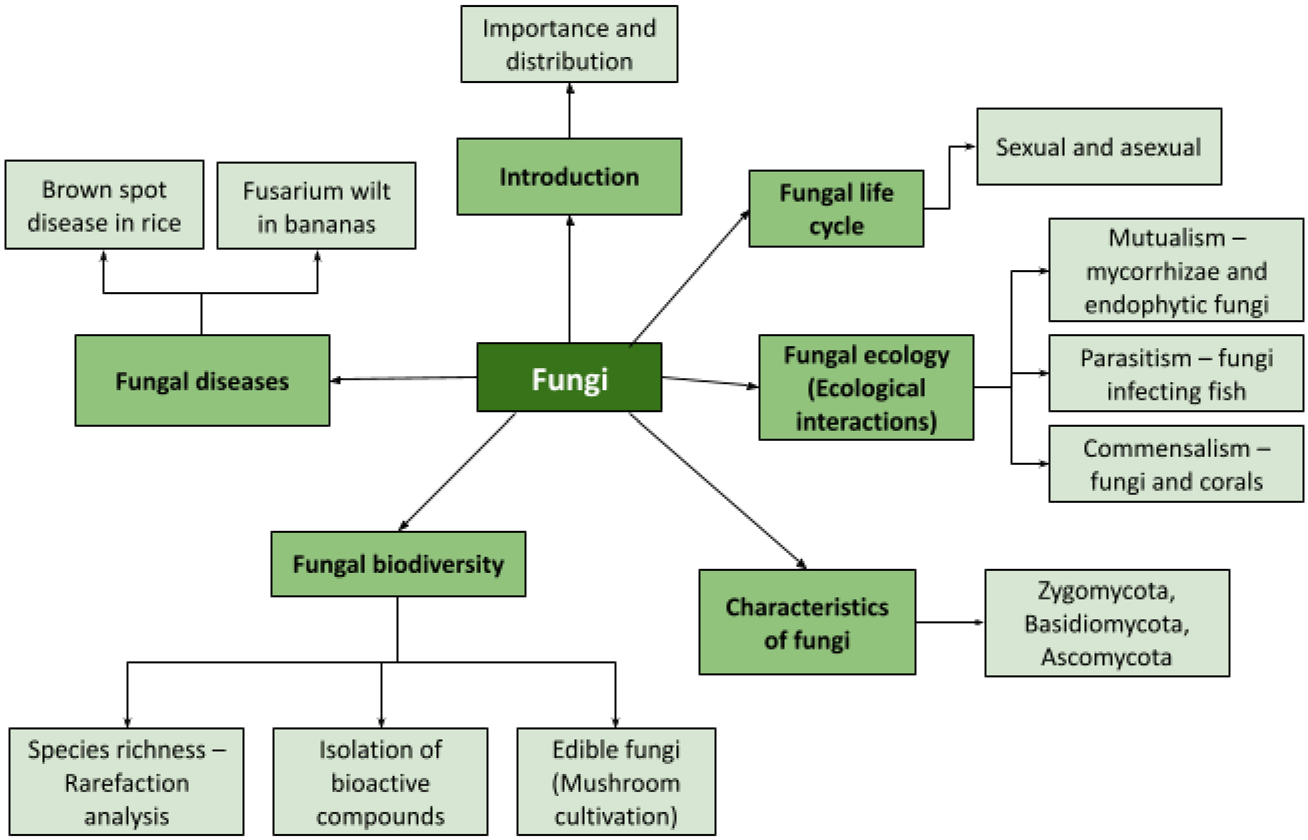
Content Mapping

This table will help you map parts of your syllabus to the content and capacity-building approach in iThinkBiology. In the first column, you will find units and topics from your syllabus and the subsequent columns contain the sections, subsections and concepts from our book iThink Biology. By using this table, you can easily identify the relevant concepts from the book that align with your syllabus.

Existing Syllabi	Corresponding Topics in iThink Biology			
Subject, Topic	**Headings/ Sections**	**Subsection**	**Concepts explored**	**Capacities**
Mycology, Introduction	Introduction	Introduction to Fungi	Basic introduction to fungi, examples	Reading and Interpreting
Mycology, Definition; **Microbial diversity**, Modes of reproduction: Asexual and sexual; **Symbiotic associations,** Mycorrhiza**,** Commensalism, parasitism	Fungal life cycle and ecology	Life cycle of fungi	Structure of fungi, sexual and asexual reproduction in fungi	Reading and Interpreting; Scientific Process
		Ecological relationships between fungi and other organisms	Mutualism - mycorrhizae (wood wide web), endophytic fungi; Commensalism; parasitism	Reading and Interpreting
Mycology, Fungi: General characteristics; Microbial diversity (Fungi); **Ecology,** Species richness (Rarefaction analysis)	Fungal biodiversity	Characteristics of some phyla of fungi	Fungal taxonomy, Zygomycota, Basidiomycota, Ascomycota	Reading and Interpreting; Scientific Process
		Fungal Biodiversity in India	Marine fungi, conservation of fungal biodiversity; Extra reading - Prof CV Subramanian	Quantitative skills
		Rarefaction analysis	Endophytic fungi, accumulation curve, rarefaction curve, species richness	Quantitative skills
Applied Mycology, Medical mycology, role of fungi in biotechnology,	Harnessing fungal biodiversity	Bioactive compounds	New drugs and insecticides	Reading and Interpreting
		Identifying fungi	Endophytic isolates,	Scientific tools

secondary metabolites (isolation and identification); **Mycology,** mushroom cultivation		that produce antimicrobial compounds	control setup, zone of inhibition, antimicrobial potency	
		Identifying bioactive molecules produced by fungi	Isolation and identification of bioactive molecules, chromatography and spectroscopy	Scientific tools
		Edible fungi, Mushroom cultivation	Indigenous knowledge of edible mushrooms, the importance of mushroom cultivation	Bridging science, society and the environment
Phytopathology, Fungal diseases: brown spot disease, Fusarium wilt; **Biopesticides**, *Trichoderma*	Fungal diseases	*Cochliobolus miyabeanus* and the 1943 Bengal famine	Brown spot disease in rice crop, food supply reduction, wind dispersal of spores, fungicides, biological control	Reading and Interpreting; Bridging science, society and environment
		Fusarium wilt and bananas	Mechanisms for spread of Fusarium wilt, Cavendish cultivars, TR4 infection, soil solarisation	Reading and Interpreting; Bridging science, society and environment

Concepts introduced in the chapter



Capacities developed in this chapter

You will notice that every chapter has a set of questions appearing at the beginning of the chapter. These describe the content (indicated by the questions) related to the capacity (indicated by the icon).

CAPACITIES TAUGHT IN THIS CHAPTER

- How do fungi grow? What are some of the ecological functions they carry out? What impact do fungal diseases have on agricultural plants?
- How do we characterise fungal biodiversity?
- How can we determine if a particular location has more fungal species?
- Can mushroom cultivation provide food security? Can we harness indigenous knowledge of edible mushrooms and their medicinal properties?
- How can we identify bioactive compounds from fungi?

In this guide, we have followed different subsections from the ithinkbiology book. We have suggested different activities that are focussed on answering the critical thinking questions given in the book. We have added two annexures to this guide.

Notes for Instructors

In this document, we provide some suggestions for instructors on how to get students to engage with the critical thinking questions that are present throughout the chapter. We have provided the answers and suggested activities for each section in the book. It would be ideal to use these questions along with the book chapter but do adopt these questions and activities to related topics in your curriculum. We hope that this document encourages you to create similar critical thinking questions for the concepts in your course syllabus.
In our experience, there is much value in group work conducted between students. If a student can be accompanied by even one other student while attempting some of the exercises, it will make a

difference in their learning experience. If you do conduct these exercises in groups, ensure that the group sizes are not too large (not more than 5 students per group) so that all the students participate in the discussions. Students tend to be curious but having a few pre-prepared questions and hints to promote conversation in groups might be helpful.

A wrap-up discussion to combine and connect the individual group learnings is essential to ensure learning objectives are achieved. Do keep some extra time while conducting group work since they tend to run longer than the time estimated.

Activity-1

Teachers' Handout

Topics covered: D3.1 Introduction

Capacity: Reading and Interpreting

Learning outcomes:

- Characteristics of fungi and how they differ from plants and animals.
- Roles of fungi in ecosystems

Grades: Undergraduate, 12th (can be tailored for lower grades)

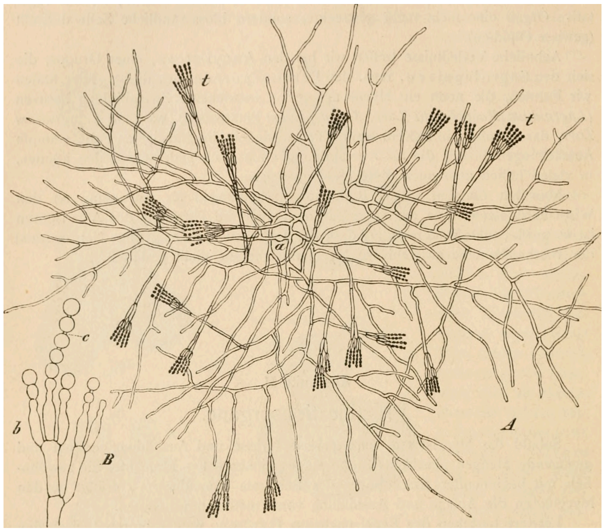
Suggested time *- 1 class*

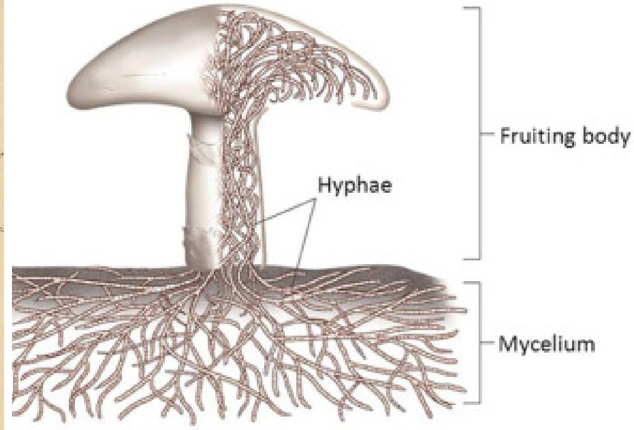
Start the class by introducing students to the 'Fungi'. Ask them what the meaning of fungi is. Brainstorm with them the identifying characteristics of different kingdoms and differences between plants, animals and fungi.
Ask them the following questions:

- When you think of macroscopic life forms, what organisms come to mind?
- What are the similarities and differences between
  - a fig tree and a mushroom?
  - a honeybee and a mushroom?
  - yeast, penicillium and mushroom?
- Where can you find fungi? Where does it grow?
- What do fungi eat?
- Why do we sometimes confuse fungi with plants? Why were fungi placed in the Plant Kingdom for a long time?
- What roles do fungi play in nature that differ from plants and animals?
- Are fungi multicellular or unicellular?

Discuss these questions in your classroom and note down the points that students come up with.

- Ask students to draw what multicellular fungi look like under the microscope. Can they point out which part is a cell?
- If possible, provide students with prepared slides of multicellular fungi under microscopes. Encourage them to observe the structures and sketch what they see. Ask them to label the individual cells within the fungal structures. Alternatively, provide images of fungal structures to students and ask them to label cells.





Penicillium under a microscope
(a – hyphae, b – basidia, c – conidia, t – conidiophores)
Wikimedia Commons, public domain-US

Structure of a mushroom

Share these images with students and ask them to label cells or the part where they will find cells. Explain to them that the hyphae are made up of many cells. Explain the structure of fungi in detail.

<u>What does this activity make students do?</u>

This activity will introduce students to fungi and encourage discussion in the classroom. Students will explore the characteristics of fungi and their similarities and differences from other organisms. They will gain a better understanding of the structure of a fungus.

Extension activity:

Encourage students to go on a 'treasure hunt' for fungi in their neighbourhood. Ask them to look for mushrooms, moulds or lichens. Discuss safety guidelines with them for outdoor exploration and instruct them not to touch, pluck or consume any fungi.

- Encourage them to take pictures, make sketches, and note down observations of the fungi they find. Observe the colours and structure of different fungi.
- Ask them to compile their findings in a journal.
- Note down the surrounding environment where a particular fungus was found.
- Encourage them to write about any similarities and differences among the fungi they found. Ask them to think and write about the roles of fungi they found in ecosystems.

Activity-1

Teachers' Handout (Answer key)

Topics covered: D3.1 Introduction

Capacity: Reading and Interpreting

Learning outcomes:

- Characteristics of fungi and how they differ from plants and animals.
- Roles of fungi in ecosystems

Grades: Undergraduate, 12th (can be tailored for lower grades)

Suggested activity

***Suggested time** - 1 class*

Start the class by introducing students to the 'Fungi'. Ask them what the meaning of fungi is. Brainstorm with them the identifying characteristics of different kingdoms and differences between plants, animals and fungi.
Ask them the following questions:

- When you think of macroscopic life forms, what organisms come to mind?

  Students might mention animals like mammals, birds, reptiles, amphibians, insects, or larger plants like trees, bushes, flowers, etc.
  Encourage them to think about fungi and their examples.

- What are the similarities and differences between
  - a fig tree and a mushroom?

    A fig tree belongs to the kingdom Plantae. Mushrooms belong to the kingdom of Fungi. Like plants, fungi also are immovable but lack chlorophyll and cannot produce their own food. They typically grow in moist environments. Mushrooms are part of fungi, not plants. Fungi also has a cell wall like plants but it is made up of chitin.

  - a honeybee and a mushroom?

    A honeybee is an insect, while a mushroom is a fungus. Bees belong to the kingdom Animalia. Animals can move around in search of food and shelter, mushrooms, on the other hand, don't have mobility and obtain nutrients through decomposition. The cell wall of mushrooms is made up of chitin, which is also found in the exoskeleton of some insects.

  - yeast, penicillium and mushroom?

    Yeast, penicillin and mushrooms are all types of fungi. Yeast is a unicellular fungus used in baking and fermentation. *Penicillium* is a genus of mould fungi characterised by its filamentous structure. A mushroom is a macroscopic fungus. It is the fruiting body of certain fungi belonging to various genera and species, often found in various shapes, sizes, and environments.

- Where can you find fungi? Where does it grow?

  Fungi can be found almost everywhere - in soil, on plants, in water, and even in the air. They usually prefer dark and humid environments to grow. Scientists have even isolated fungi from the screens of smartphones. They grow in diverse habitats ranging from forests and grasslands to human-made environments like bathrooms and kitchens. You can find fungus growing on spoiled food.

- What do fungi eat?

  Fungi decompose and obtain nutrients by breaking down organic matter like dead plants, animals, and other organic materials. They are also called recyclers of nature. Some fungi also live as symbionts, obtaining nutrients from their partners.

- Why do we sometimes confuse fungi with plants? Why were fungi placed in the Plant Kingdom for a long time?

  Fungi were historically placed in the Plant kingdom because of their immobile nature, similar growth form (mushrooms resembling some plants), and presence of a cell wall. However, now we know they are unique and differ in cell structure, reproduction, and nutritional habits. This led to their reclassification into a separate kingdom Fungi.

- What roles do fungi play in nature that differ from plants and animals?

  Fungi play critical roles in decomposition, breaking down dead matter and recycling nutrients back into the ecosystem. They also form symbiotic relationships with plants (mycorrhizae), aiding in nutrient absorption.

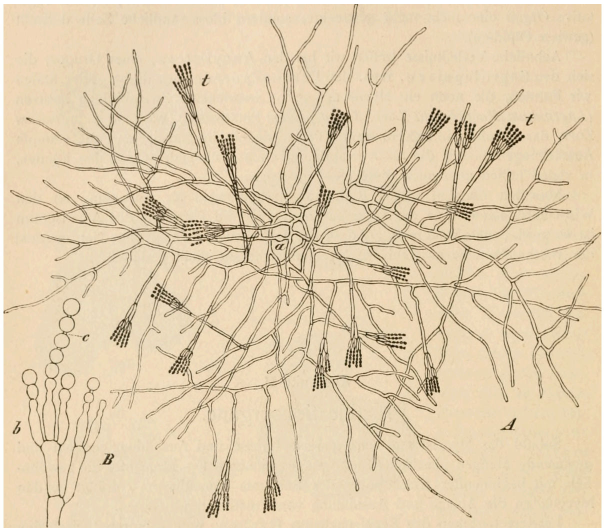
- Are fungi multicellular or unicellular?

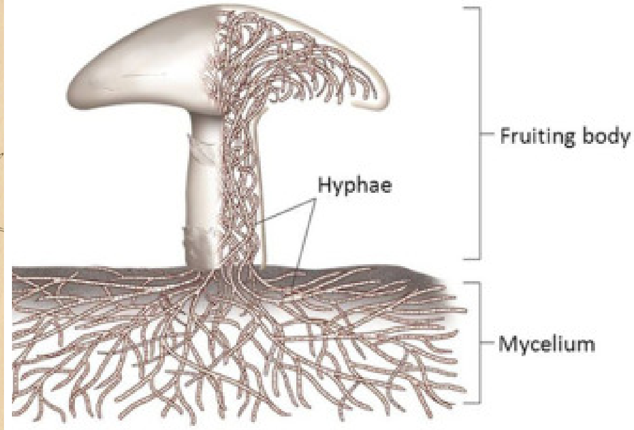
  Fungi can be both multicellular and unicellular. Yeast is unicellular fungi and other genera of fungi are multicellular.

Discuss these questions in your classroom and note down the points that students come up with.

Please note that these answers are provided for reference only, answers may differ based on the discussion in a classroom.

- Ask students to draw what multicellular fungi look like under the microscope. Can they point out which part is a cell?
- If possible, provide students with prepared slides of multicellular fungi under microscopes. Encourage them to observe the structures and sketch what they see. Ask them to label the individual cells within the fungal structures. Alternatively, provide images of fungal structures to students and ask them to label cells.





Penicillium under a microscope

(a – hyphae, b – basidia, c – conidia, t – conidiophores)

Wikimedia Commons, public domain-US

Structure of a mushroom

Share these images with students and ask them to label cells or the part where they will find cells. Explain to them that the hyphae are made up of many cells. Explain the structure of fungi in detail.

Structure of Fungi:

- **Hyphae (sing. hypha)**: These are the long, thread-like structures that form the primary structural components. Hyphae can be septate (divided by septa with pores allowing cell-to-cell communication) or coenocytic (lacking septa, containing multinucleated cytoplasm without distinct cell boundaries). Each hypha comprises individual fungal cells whose cell walls are made up of chitin.
- **Mycelium**: Hyphae branch and intertwine to form a network called mycelium. Mycelium is the vegetative, growth phase of fungi and functions like the root system of the fungus. It spreads and penetrates its substrate to absorb nutrients.
- **Reproductive Structures**: Fungi produce various types of reproductive structures. These might include spores, which are dispersed to new locations for reproduction. Reproductive structures vary widely among different fungal groups and species.
- **Fruiting Bodies**: In many fungi, specialised structures called fruiting bodies develop to house reproductive structures (like spore-bearing structures). Examples include mushrooms, puffballs, and more.

What does this activity make students do?

This activity will introduce students to fungi and encourage discussion in the classroom. Students will explore the characteristics of fungi and their similarities and differences from other organisms. They will gain a better understanding of the structure of a fungus.

Extension activity:

Encourage students to go on a ‘treasure hunt’ for fungi in their neighbourhood. Ask them to look for mushrooms, moulds or lichens. Discuss safety guidelines with them for outdoor exploration and instruct them not to touch, pluck or consume any fungi.

- Encourage them to take pictures, make sketches, and note down observations of the fungi they find. Observe the colours and structure of different fungi.
- Ask them to compile their findings in a journal.
- Note down the surrounding environment where a particular fungus was found.
- Encourage them to write about any similarities and differences among the fungi they found. Ask them to think and write about the roles of fungi they found in ecosystems.

Students' Handout

In this class, you will be introduced to the kingdom of Fungi.

1. When you think of macroscopic life forms, what organisms come to mind?

2. What are the similarities and differences between
   - a fig tree and a mushroom?
   - a honeybee and a mushroom?
   - yeast, penicillium and mushroom?

3. Where can you find fungi? Where does it grow?

4. What do fungi eat?

5. Why do we sometimes confuse fungi with plants? Why were fungi placed in the Plant Kingdom for a long time?

6. What roles do fungi play in nature that differ from plants and animals?

7. What do multicellular fungi look like under the microscope? Label the cell.

Activity-2

Teachers' Handout (Answer key)

Topics covered: D3.2 Fungal life cycle and ecology

Capacity: Scientific Process; Scientific Tools

Learning outcomes:

- Understanding of the scientific process.
- Conducting controlled experiments and learning laboratory etiquette.
- Documenting and analysing data.

Grades: Undergraduate, 12th (can be tailored for lower grades)

Question

Look at the figure given below. You will notice that there are patches of different colours. How would you explain the different colours? How will you investigate this question?

Mould growing on bread

Hint

Do different fungi vary in colour? Are stages of the life cycle of a fungus different colours? Think about observing the process over time.

Answer

The appearance of different-coloured patches on bread over time is most likely due to the growth of various moulds. However, some species of mould also vary in colour in their vegetative and reproductive phases. Mould spores are everywhere in the environment, and when they land on a suitable surface like bread (which is rich in nutrients and moisture), they start to grow.

Suggested time *- A couple of weeks*

Read the subsection 'The Scientific Process' in the chapter Western Ghats to learn about the steps of scientific discovery.

Engage students by discussing the intriguing patterns and colours observed in mould growth on bread slices. Encourage them to brainstorm hypotheses about why different-coloured patches appear on mouldy bread over time. To test this question, encourage students to come up with an experiment.

Observation – Moulds growing on bread have different patches of colour.

Hypothesis – Different-coloured patches on bread over time are due to the growth of different types of moulds.

Encourage students to brainstorm and propose reasons to support or challenge this hypothesis. Below is one of the ways to conduct this experiment. Encourage students to change variables in their experimental setup.

Materials – Several slices of bread, ziplock bags or containers, a water spray bottle, gloves, notebooks or experiment journals, and cameras.

Experiment –

1. Take 3 bread slices (or more, depending on available variables) and sprinkle a small amount of water on each bread.
2. Keep these breads in separate ziplock bags and label them.
3. Leave the bags undisturbed in a warm place outside your house/classroom to facilitate mould growth.
4. Check the bags every day and track the growth of the mould.
5. Once the mould starts to grow, record your observations for 2 weeks. Collect data in the notebook on the size and colour of the colony.
6. Use cameras to capture images of the bread slices each day to create a visual timeline.
7. Measure the size of mould colonies if possible, using rulers.

Observations guidelines –

From the first day, observe the bread slices for any signs of mould growth. Observe it every day and record the patterns or any colour changes. Once the mould begins to appear, monitor that area carefully. Observe if the colour changes over time at the same location. Document when the mould first appears and whether it exhibits consistent colours in each observed spot.

Observation table

Day	Sample	Environmental Condition	Observation of Mould Growth	Mould Colour	Mould Texture	Notes
1	Slice A					
1	Slice B					
1	Slice C					
2						

Optionally, if available, examine mould samples under microscopes to observe differences or similarities.

Precautions

- Wear gloves when handling bread/mould. Wear a mask to avoid inhaling the mould spores.
- Make sure you observe the bread samples every day at the same time.
- Do not open the zip-locking plastic bag, or remove the mould samples.

Analysis and Conclusion

- After the observation period, encourage students to compile their data, analyse trends, and draw conclusions.
- Facilitate discussions or presentations where students can share findings, compare results, and collectively interpret the data.
- Reflect on the initial hypothesis and determine if the results support or challenge it.

Encourage students to come up with their own hypothesis and an experiment to test their hypothesis.

Some examples are –

- *Variable Testing*: Encourage students to introduce different variables (moisture, temperature, light exposure) into their experiments. For example,
    - they could vary the amount of moisture on different slices of bread, or
    - they could expose some slices to sunlight while keeping others in dark areas, or
    - They could place some slices in sunlight and some in the fridge.

  This allows for a deeper exploration of how various conditions affect mould growth.
- *Multiple Bread Types*: Try using different types of bread (white, wheat, multigrain, etc.) to see if mould growth rates or types vary based on the bread's composition.
- Instead of adding water, try different items, such as lemon juice, sugar water, salt water, etc.

Note: Different groups of students can test different hypotheses for their experiment. After all groups have conducted the experiments, have a discussion on different experiments. Ask students to reflect on the following questions:

- What did you learn about mould growth on bread?
- How did varying conditions affect the mould growth?
- What was the most surprising finding from your observations?

<u>What does this activity make students do?</u>
Through this activity, students will develop critical thinking and analytical skills through scientific experimentation.

Students' Handout

Name: ___________________________ Date: ____________________________

Title: Exploring Mould Growth on Bread

Observation – ____

Section 1: Hypotheses

Hypothesis Generation: Write down at least two hypotheses explaining why different-coloured patches appear on mouldy bread over time.

Hypothesis 1: ____

Hypothesis 2: ____

Section 2: Experiment Setup

Experiment Setup: Design an experimental set up to explore mould growth on bread. Include the materials needed and the conditions required for the experiment. Use bullet points to outline your procedure.

*Materials Needed:*____

____

Procedure Outline:

Section 3: Data Collection and Observation

Daily Observations: Use the table below to record your daily observations of mould growth on the bread slices. Note any changes, colours, or patterns observed.

Day	Sample	Environmental Condition	Observation of Mould Growth	Mould Colour	Mould Texture	Notes
1	Slice A					
1	Slice B					
1	Slice C					
2						

Visual Timeline: Use the space below to draw or paste images of the bread slices each day, showing the progression of mould growth.

Section 4: Analysis and Conclusion

Write a conclusion based on your observations and data collected.

Use these guiding questions to write your conclusion:

- What patterns or changes did you observe in the mould growth?
- Did the mould exhibit different colours or textures over time?
- Did your hypotheses align with the observations? Explain.

Activity-3

Teachers' Handout

Topics covered: D3.2 Fungal life cycle and ecology

Capacity: Reading and Interpreting,

Learning outcomes:
- Understanding the role of and challenges faced by marine fungi.
- Understanding of adaptations of marine fungi for survival.

Grades: Undergraduate

Question
Life in marine environments is very different from terrestrial ones. What are some of the environmental/ecological factors that marine fungi need to be adapted to?

Hint
Think of salinity and osmoregulation, availability of nutrients, exposure to ultraviolet radiation, and lack of wind dispersal.

Answer
Marine fungi face many challenges as compared to terrestrial fungi, such as high salinity, nutrient fluctuations, and UV radiation. They have various ecological adaptations to survive in marine environments.

***Suggested time** - 1 class*

Suggested Activity

1. Introduction

- Begin with a discussion about the differences between terrestrial and marine environments. Ask students to brainstorm the differences and write them on the board.
- Introduce the concept of marine fungi and focus on the challenges faced by marine fungi.
- Discuss the role and significance of fungi in marine ecosystems

2. Adaptations Exploration (Group activity by students)

- Divide students into small groups of two or three and give each group a specific adaptation of marine fungi to focus on. Example:
    Group 1: Osmoregulation
    Group 2: UV Radiation Tolerance
    Group 3: Nutrient Utilisation
    Group 4: Spore Dispersal
    Group 5: Hydrostatic pressure

- Task each group with researching and discussing the chosen adaptation, including how marine fungi have evolved to address this particular challenge in their environment.

- Groups should create visual presentations or posters summarising their findings, using diagrams, examples, and text to illustrate the adaptation and its significance.

3. Presentation and Discussion

- Have each group present their findings to the class, explaining the adaptation they researched, showcasing their visual aids, and highlighting key points.
- Encourage class discussion after each presentation, allowing students to ask questions and share their thoughts on the adaptations discussed.
- Use the board to create a summary of the adaptations covered during the presentations.
- Summarise the main points covered during the activity, emphasising the diversity of adaptations that marine fungi have evolved.
- Encourage students to reflect on the importance of these adaptations in maintaining ecological balance in marine ecosystems.

What does this question make students do?
This teaching activity encourages students to explore and appreciate the incredible adaptations of marine fungi, fostering a deeper understanding of their vital role in the dynamic and diverse world of marine ecosystems.

Activity-3

Teachers' Handout (Answer key)

Topics covered: D3.2 Fungal life cycle and ecology

Capacity: Reading and Interpreting,

Learning outcomes:

- Understanding the role of and challenges faced by marine fungi.
- Understanding of adaptations of marine fungi for survival.

Grades: Undergraduate

Question

Life in marine environments is very different from terrestrial ones. What are some of the environmental/ecological factors that marine fungi need to be adapted to?

Hint

Think of salinity and osmoregulation, availability of nutrients, exposure to ultraviolet radiation, and lack of wind dispersal.

Answer

Marine fungi face many challenges as compared to terrestrial fungi, such as high salinity, nutrient fluctuations, and UV radiation. They have various ecological adaptations to survive in marine environments.

***Suggested time** - 1 class*

Suggested Activity

4. Introduction

- Begin with a discussion about the differences between terrestrial and marine environments. Ask students to brainstorm the differences and write them on the board.

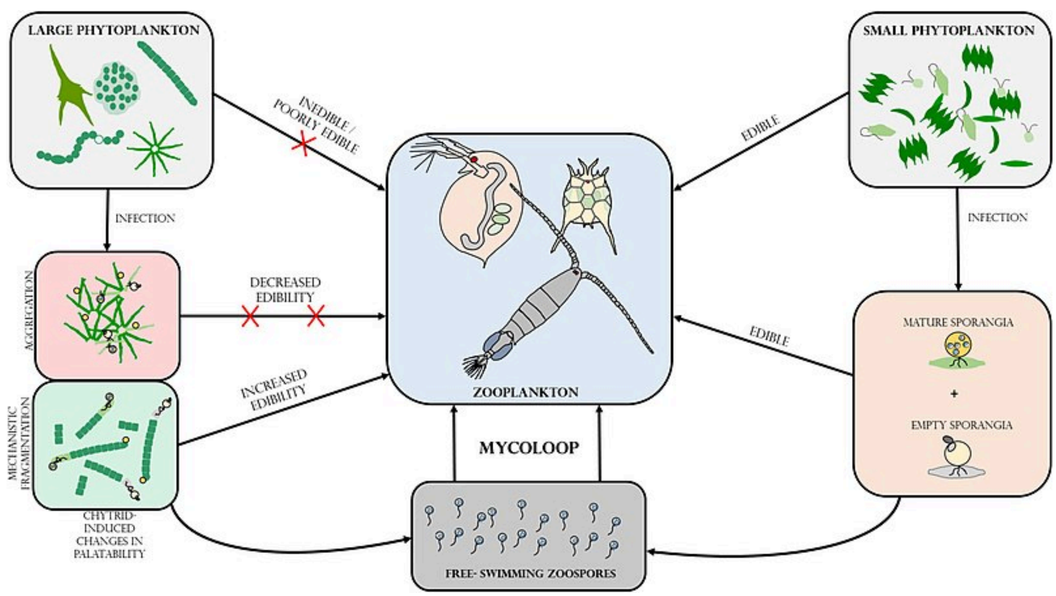
Terrestrial environment	**Marine environment**
It includes soil and air.	It includes oceans, seas, and estuaries.
Low to no salinity.	High salinity levels.
Generally, ample light is present.	Light availability decreases with depth.
Usually, nutrients are abundant in soil.	Nutrient availability can vary with depth and different areas.
Oxygen is available from the air.	Dissolved oxygen availability could vary.
Organisms regulate osmolarity internally.	Organisms must regulate osmolarity to prevent dehydration or water intake.

- Introduce the concept of marine fungi and focus on the challenges faced by marine fungi.

  Marine fungi are found in deep ocean to coastal ecosystems. There are two types of marine fungi: obligate and facultative. Obligate marine fungi grow and produce spores exclusively in a marine or estuarine habitat; while facultative marine fungi are usually found in freshwater or terrestrial ecosystems but they can grow and produce spores in marine environments. Most marine fungi are found in association with plants, animals or on dead decaying matter.
  Marine fungi face a lot of challenges compared to their terrestrial counterparts. Firstly, they have to tolerate high salinity, exposure to ultraviolet light, low temperatures, high hydrostatic pressure, and limited access to substrates for growth.

- Discuss the role and significance of fungi in marine ecosystems.

  The role of marine fungi is the degradation of dead organisms, thus, recycling organic matter. They also form symbiotic relationships (commensals, mutualists) with other marine life and also occur as parasites in some. Some studies have shown the potential of some marine fungi in the degradation of plastic.
  One of the interesting roles of marine fungi is bridging the trophic linkages between larger phytoplanktons and zooplanktons through the 'mycoloop'. Larger phytoplankton present in marine ecosystems are usually inedible to zooplankton. Chytrids (a division of fungi) are parasites on these larger phytoplankton and extract nutrients and energy from their hosts in the form of zoospores. These nutritional zoospores are prey for zooplankton, providing nutrients to them. Additionally, hosts fragmented by chytrids can also be eaten by other organisms. However, infected host colonies can also remain inedible due to aggregation of cells.



Mycoloop links between phytoplankton and zooplankton

5. <u>Adaptations Exploration (Group activity by students)</u>

- Divide students into small groups of two or three and give each group a specific adaptation of marine fungi to focus on. Example:
    - Group 1: Osmoregulation
    - Group 2: UV Radiation Tolerance
    - Group 3: Nutrient Utilisation
    - Group 4: Spore Dispersal
    - Group 5: Hydrostatic pressure

- Task each group with researching and discussing the chosen adaptation, including how marine fungi have evolved to address this particular challenge in their environment.
- Groups should create visual presentations or posters summarising their findings, using diagrams, examples, and text to illustrate the adaptation and its significance.

Here are some of the adaptations that teachers can discuss in the class.

- *Osmoregulation* – In marine environments, maintaining the right balance of water and solutes is crucial. High salinity of seawater can lead to osmotic and ionic stresses. Marine fungi have many salt efflux pumps in their cell membranes, allowing them to remove excessive salt. When fungi encounter high external solute concentrations, they activate the high-osmolarity-glycerol signalling pathway. This pathway helps them adjust their internal ion balance, actively pump out salts, and produce compatible osmolytes like glycerol.

- *UV Radiation Tolerance* – In marine environments, organisms are exposed to high levels of ultraviolet (UV) radiation. Marine fungi have evolved strategies to cope with UV radiation, such as the production of protective pigments (e.g. melanin). The prevalence of black yeasts which produces high levels of melanin may be attributed to the need for increased UV protection in saline conditions.

- *Production of gels and slime* – Many wood-decaying marine fungi produce gels and slimes to retain secreted enzymes at the substratum.

- *Presence of flagellum* – Some marine fungi have evolved a flagellum that allows movement in water. This adaptation is particularly common in chytrids and cryptomycetes. However, the efficiency of flagellum is debated in coastal ecosystems with strong tidal forces.

- *Spore Dispersal*: Wind dispersal, common among terrestrial fungi, is not applicable in marine environments. Certain groups of filamentous fungi in the Ascomycota and Basidiomycota phyla have developed spore adaptations such as extensive appendages on spores. These appendages can serve to keep the spores in the water column for longer periods, increasing the chances of dispersal to new locations.

- *Hydrostatic pressure tolerance* – Fungi in deep-sea environments have evolved adaptations at the transcriptional or protein-coding level to cope with the challenges posed by extreme hydrostatic pressures.

- *Nutrient Utilisation*: Nutrient availability in marine environments can be variable. Marine fungi have adapted to extract and utilise nutrients efficiently, often forming symbiotic relationships with other marine organisms for mutual benefit.

6. <u>Presentation and Discussion</u>

- Have each group present their findings to the class, explaining the adaptation they researched, showcasing their visual aids, and highlighting key points.
- Encourage class discussion after each presentation, allowing students to ask questions and share their thoughts on the adaptations discussed.
- Use the board to create a summary of the adaptations covered during the presentations.
- Summarise the main points covered during the activity, emphasising the diversity of adaptations that marine fungi have evolved.
- Encourage students to reflect on the importance of these adaptations in maintaining ecological balance in marine ecosystems.

References:

- Cunliffe, M. (2023). Who are the marine fungi?. *Environmental Microbiology*, *25*(1), 131.
- Gladfelter, A. S., James, T. Y., & Amend, A. S. (2019). Marine fungi. Current Biology, 29(6), R191-R195.
- Gonçalves, M. F., Esteves, A. C., & Alves, A. (2022). Marine fungi: Opportunities and challenges. *Encyclopedia*, 2(1), 559-577. https://doi.org/10.3390/encyclopedia2010037
- Zeghal, E., Vaksmaa, A., Vielfaure, H., Boekhout, T., & Niemann, H. (2021). The potential role of marine fungi in plastic degradation–a review. Frontiers in Marine Science, 8, 738877.

What does this question make students do?

This teaching activity encourages students to explore and appreciate the incredible adaptations of marine fungi, fostering a deeper understanding of their vital role in the dynamic and diverse world of marine ecosystems.

Students’ Handout

Topic: Exploring Marine Fungi Adaptations

You will be divided into small groups of two or three.
Adaptation: Each group will focus on one adaptation of marine fungi (e.g., osmoregulation, UV radiation tolerance, nutrient utilisation, spore dispersal).

Research and Presentation:

- Research how marine fungi have adapted to the assigned factor.
- Create a visual presentation or poster summarising your findings.
- Consider using diagrams, examples, and text to illustrate the adaptation and its significance.

Presentation and Discussion:

- Each group presents their findings to the class.
- Discuss each adaptation, encouraging questions and reflections.
- Summarise the main points on the board.

Reflection:

- Write a brief reflection on what you've learned about marine fungi adaptations.
- Consider the importance of these adaptations in maintaining ecological balance in marine ecosystems.

Activity-4

Teachers' Handout

Topics covered: D3.2 Fungal life cycle and ecology

Capacity: Reading and Interpreting; Bridging science, society and the environment

Learning outcomes:

- Understanding ecological relationships between fungi and other living organisms.
- Understanding the interconnected nature of ecosystems

Grades: Undergraduate, 12th (can be tailored for lower grades)

***Suggested time** - 1 class*

- Instruct students to read the subsection 'Ecological relationships between fungi and other organisms'. Explain that for this activity, they will explore a hypothetical forest where fungi do not exist.
- Divide students into different groups. Assign each group specific roles or functions related to fungi, for example –
    - Group 1 – Nutrient Recyclers
    - Group 2 – Decomposers
    - Group 3 – Mycorrhizal Partners
    - Group 4 – Lichen symbionts

- Instruct each group to draw a forest ecosystem without fungi. Encourage them to think about how the absence of fungi might affect various elements, such as nutrient distribution, plant health, and animal life.
- Each group will present their fungus-free forest to the class, explaining the changes they made and the potential consequences of the absence of fungi in their ecosystems.

  Note – students don't need to be artistic to do this activity. They can use symbols to illustrate their fungus-free forest. The primary aim is to deepen their understanding of fungi's role in the ecosystem.

- Facilitate a class discussion by asking questions such as:
    - What were the major changes in the forest ecosystems without fungi?
    - How might the absence of fungi impact the survival of different species in the forest?
    - How might plants obtain necessary nutrients in the absence of mycorrhizal partnerships?
    - How the absence of fungi in a forest ecosystem might affect the availability of resources for local communities
- Summarise the key points and emphasise the importance of fungi in maintaining a healthy forest ecosystem.

Reflection

Ask students to write in 200-250 words how this activity has changed their perception of the importance of fungi in ecosystems.

Suggested videos:

Consider showing any of these videos in the class to explore how the world without fungi looks

1. https://www.history.com/videos/a-world-without-fungi
2. https://www.youtube.com/watch?v=UKWTbxWUxH0

Students' Handout

Topic: Fungi in the Forest: Understanding Ecological Relationships

Capacity: Reading and Interpreting; Bridging science, society and the environment

Introduction

In this activity, we will explore the intricate relationships between fungi and other living organisms in a forest ecosystem. Imagine a hypothetical forest where fungi do not exist. Your task is to analyse and illustrate the potential consequences of the absence of fungi on various elements within the ecosystem.

Instructions

- Read the subsection 'Ecological relationships between fungi and other organisms'.
- Imagine a forest without the existence of fungi.
- You will be assigned a specific role or function related to fungi. Your group's task is to draw a fungus-free forest ecosystem and explain the changes made.
- Use symbols or drawings to represent your ideas. The focus is on understanding the role fungi play in the ecosystem, not artistic skills.

Reflection

Write a 200-250 word reflection on how this activity has changed your perception of the importance of fungi in ecosystems.

Activity-5

Teachers' Handout

Topics covered: D3.3 Fungal Biodiversity

Capacity: Scientific Process, Quantitative Skills

Learning outcomes:

- Interpreting and analysing graphical representations.
- Understanding the relationship between depth below the seafloor and the number of isolates.

Grades: 12th, undergraduate

Suggested activity

Suggested time *- 1 class*

Instruct students to read the section [‘D3.3 Fungal Biodiversity’] and encourage them to do exercises D3.2 and D3.3 to build quantitative skills.

Below is a stacked bar graph depicting the fungal diversity in deep-subseafloor sediments in New Zealand. The X-axis represents depth in metres below the sea floor (mbsf) and Shannon index, while the Y-axis indicates the number of fungi isolated at various depths.

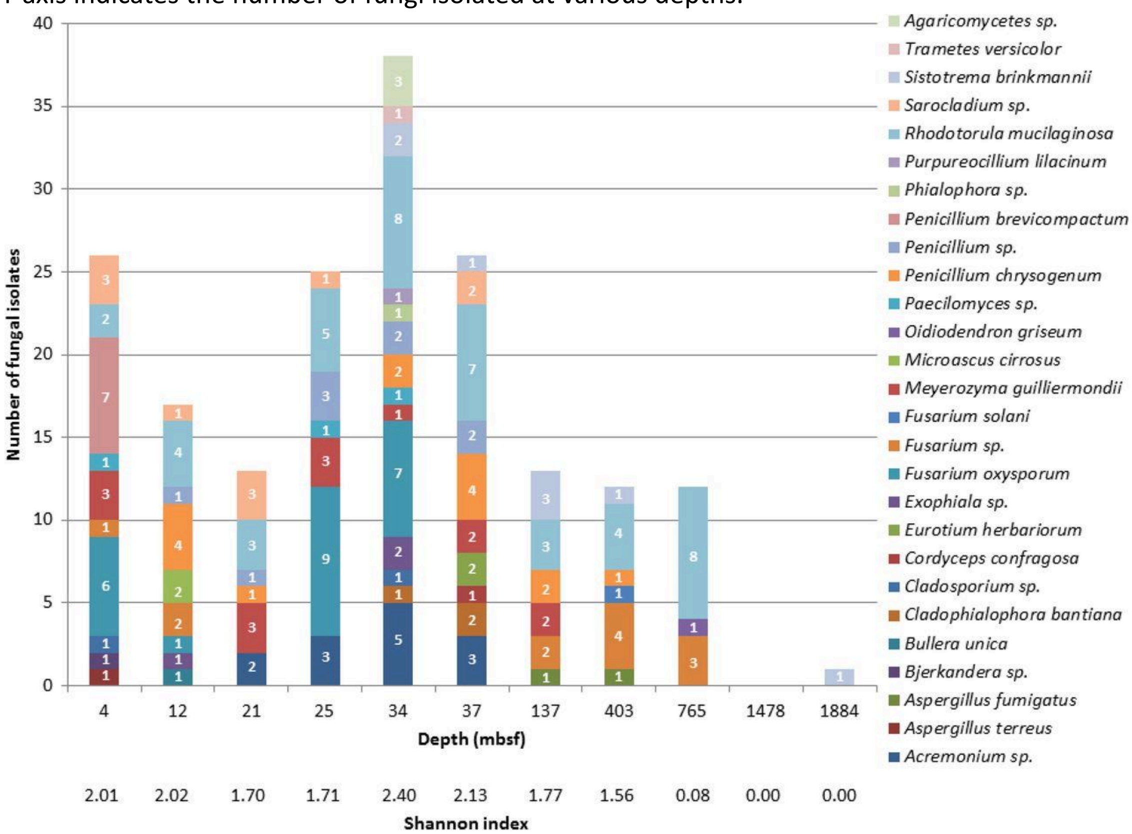


Fig – Species richness along the core. Shannon diversity indices allow the identification of the relative complexity of fungal communities at different depths.

Image credits– Rédou, V., Navarri, M., Meslet-Cladière, L., Barbier, G., & Burgaud, G. (2015). Species richness and adaptation of marine fungi from deep-subseafloor sediments. Applied and environmental microbiology, 81(10), 3571-3583.

Share the graph with students and ask them to answer the following questions.

1. How many genera were identified among the fungal isolates?
2. What do the numbers written within the bars represent?
3. Write down the number of fungal species found at each depth.
4. Describe the overall trend in the number of isolates as depth increases.
5. Why do you think the number of isolates changes with depth?
6. Which depth shows the highest species richness?
7. At depths, 21 mbsf, 137 mbsf and 403 mbsf, six species are isolated. Then, why is the Shannon index different?
8. Why is it important to represent the data in a stacked bar graph for this study?

<u>What does this question make students do?</u>
This teaching activity helps students to analyse data trends and patterns in a stacked bar graph.

Activity-5

Teachers' Handout (Answer key)

Topics covered: D3.3 Fungal Biodiversity

Capacity: Scientific Process, Quantitative Skills

Learning outcomes:

- Interpreting and analysing graphical representations.
- Understanding the relationship between depth below the seafloor and the number of isolates.

Grades: 12th, undergraduate

Suggested activity

***Suggested time** - 1 class*

Instruct students to read the section 'D3.3 Fungal Biodiversity' and encourage them to do exercises D3.2 and D3.3 to build quantitative skills.
Below is a stacked bar graph depicting the fungal diversity in deep-subseafloor sediments in New Zealand. The X-axis represents depth in metres below the seafloor (mbsf) and Shannon index, while the Y-axis indicates the number of fungi isolated at various depths.

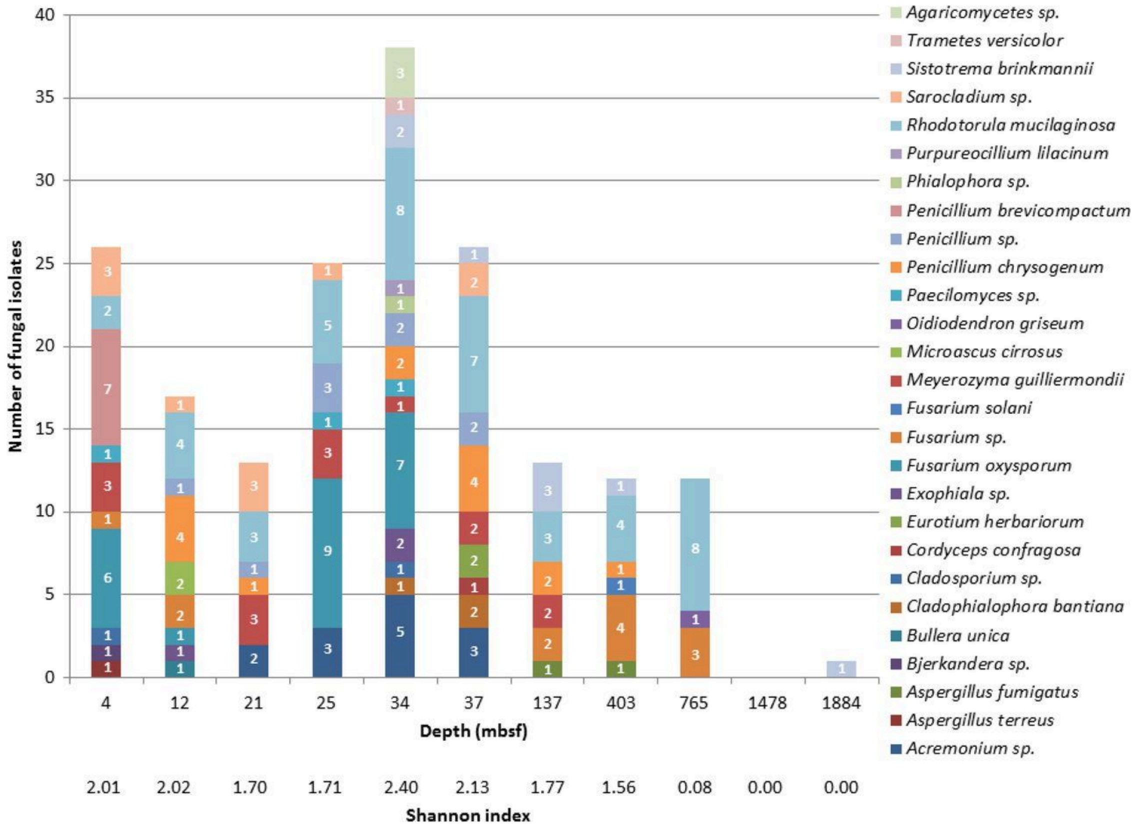


Fig – Species richness along the core. Shannon diversity indices allow the identification of the relative complexity of fungal communities at different depths.

Image credits– Rédou, V., Navarri, M., Meslet-Cladière, L., Barbier, G., & Burgaud, G. (2015). Species richness and adaptation of marine fungi from deep-subseafloor sediments. Applied and environmental microbiology, 81(10), 3571-3583.

Share the graph with students and ask them to answer the following questions.

1. How many genera were identified among the fungal isolates?
   22 genera have been given in the graph.

2. What do the numbers written within the bars represent?
   The numbers written within the bars represent the number of fungal isolates belonging to different species (depicted in different colours) at a given depth.

3. Write down the number of fungal species found at each depth.
   The number of fungal species at each depth is
   4 mbsf – 10; 12 mbsf – 9; 21 mbsf – 6; 25 mbsf – 7; 34 mbsf – 15; 37 mbsf – 10; 137 mbsf – 6; 403 mbsf – 6; 765 mbsf – 3; 1478 mbsf – 0;1888 mbsf – 1

4. Describe the overall trend in the number of isolates as depth increases.
   As depth increases, there is a decrease in the number of isolates, especially after 34 mbsf.

5. Why do you think the number of isolates changes with depth?
   The number of isolates changes with depth due to variations in environmental conditions, such as temperature, pressure, and nutrient availability, which can influence the growth and survival of fungal communities. Different depths may provide distinct ecological niches, impacting the abundance and diversity of fungi.

6. Which depth shows the highest species richness?
   The depth of 34 mbsf shows the highest species richness.

7. At depths, 21 mbsf, 137 mbsf and 403 mbsf, six species are isolated. Then, why is the Shannon index different?
   The Shannon index takes into account both species richness and evenness. Even though six species are isolated at each depth, the relative abundance of each species is different, resulting in different Shannon index values.

   Learn more about the Shannon index in 'A1.3 Plant and animal distribution across the Western Ghats' of Chapter Western Ghats.

8. Why is it important to represent the data in a stacked bar graph for this study?
   Representing the data in a stacked bar graph allows for visualising the distribution of fungal isolates at different depths, highlighting the changes in species composition and abundance. This type of graph helps in comparing both the total and individual components of fungal diversity at each depth.

Activity-5

Student's Worksheet

Read the section 'D3.3 Fungal Biodiversity' and do exercises D3.2 and D3.3 to build quantitative skills. Below is a stacked bar graph depicting the fungal diversity in deep-subseafloor sediments in New Zealand. The X-axis represents depth in metres below the sea floor (mbsf) and Shannon index, while the Y-axis indicates the number of fungi isolated at various depths.

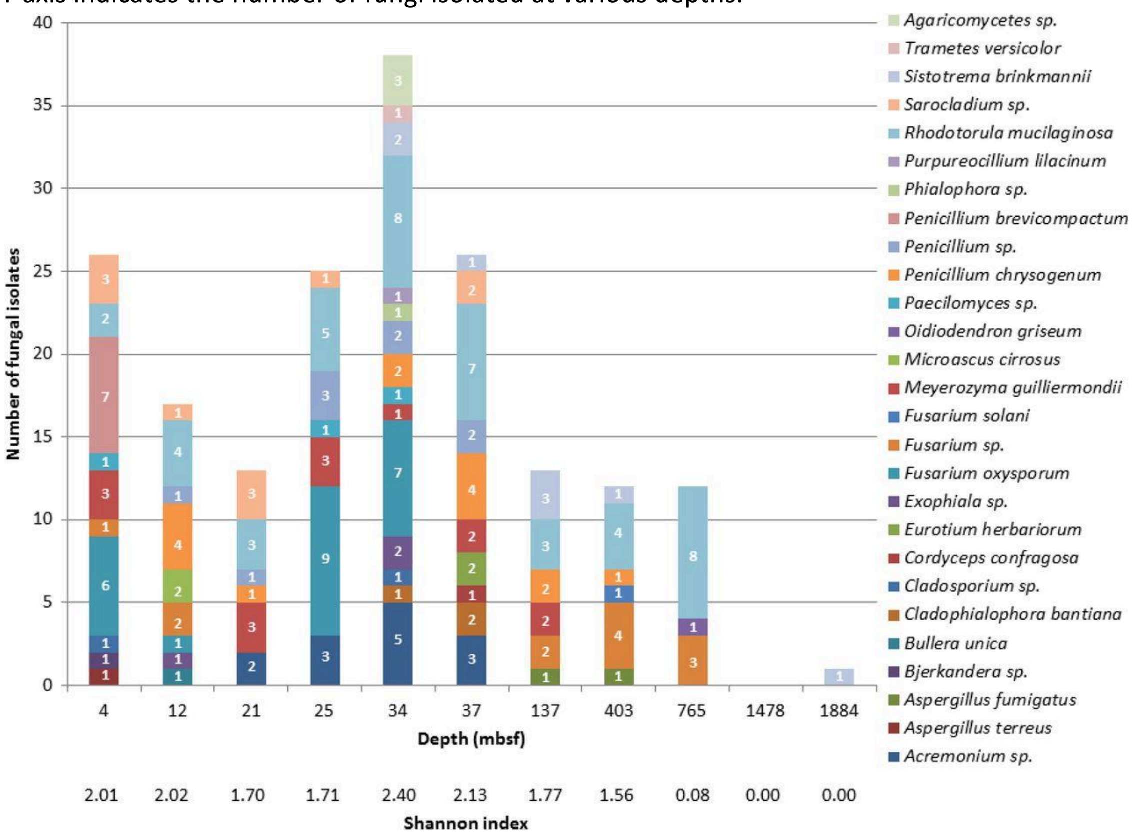


Fig – Species richness along the core. Shannon diversity indices allow the identification of the relative complexity of fungal communities at different depths.

Image credits– Rédou, V., Navarri, M., Meslet-Cladière, L., Barbier, G., & Burgaud, G. (2015). Species richness and adaptation of marine fungi from deep-subseafloor sediments. Applied and environmental microbiology, 81(10), 3571-3583.

Examine the graph carefully and answer the following questions:

1. How many genera were identified among the fungal isolates?

2. What do the numbers written within the bars represent?

3. Write down the number of fungal species found at each depth.

4. Describe the overall trend in the number of isolates as depth increases.

5. Why do you think the number of isolates changes with depth?

6. Which depth shows the highest species richness?

7. At depths, 21 mbsf, 137 mbsf and 403 mbsf, six species are isolated. Then, why is the Shannon index different?

8. Why is it important to represent the data in a stacked bar graph for this study?

Ideas!!

- Imagine a world without fungi. Create a forest?
- If you were to create a children's book, say age 4-8 years, how would you go about it? What information would you include? In the first person, you can name your character. How does the character survive? How does it navigate, and what does it eat? What relationships does it form with other organisms?
- Caterpillar fungus
  https://www.youtube.com/watch?v=b--9igdjVj0
- https://www.youtube.com/watch?v=ct3bg0CbYp4