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Education on plants and fungi in Singapore: an urgent call

Choong Mei Fun Amy

Department of Biological Sciences, Faculty of Science, National University of Singapore, 14 Science Drive 4, Singapore 117543, Republic of Singapore; Email: dbscmfa@nus.edu.sg

Abstract. Singapore was very biodiverse before it became a British colony. The study of Singapore's biodiversity began its academic roots when the University of Malaya (which later became the National University of Singapore) was set up, with the Botany Department being founded in 1949 and the Zoology Department in 1950. Over the years, education on plants and fungi in Singapore has been affected by policy changes and dwindling numbers of botanists and mycologists. There is concern about the widespread inability to identify plants and fungi and underappreciation of their importance—a trend seen globally too. Suggestions on how to overcome these challenges include adjusting the curriculum, from pre-school to university and beyond with continuing adult education. The teaching of Botany and Mycology involving the five senses may make these subjects more relatable. Botanical and mycological skills are crucial to jobs involving forest management, environmental conservation, food production, overcoming biodiversity loss and addressing the climate change crisis. As training takes time and attaining expertise will take even longer, those who are in the position to do something must act now.

Key words. Botany, Mycology, plant blindness, fungus blindness, curriculum, forest, biodiversity loss, climate change

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INTRODUCTION

Both plants and fungi provide numerous ecosystem services critical to the well-being of humankind and animals (Schaal, 2019). Fungi are critical to a healthy forest ecosystem (Frac et al., 2018) as many plants live in symbiotic relationships with mycorrhizal fungi (Feijen et al., 2018). Unfortunately, plants and fungi lack locomotion, and blend with the rest of the backdrop of green and brown in nature when not flowering or producing mushrooms; they are therefore perceived as low in value and uninteresting, unlike, e.g., predators. Moreover, plants are so different from animals that humans, including introductory biology teachers, often overlook them (Wandersee & Schussler, 1999). Furthermore, the majority of the fungi are microscopic, with only certain phyla having members that produce mushrooms visible to the naked eye. The microscopic bodies of fungi and their ephemeral 'seen today, disappear from view later' nature makes them hard to find and study, thus fungi are often overlooked.

'Plant blindness', a term coined by Wandersee & Schussler (1999), refers to the tendency for people to ignore plants or to devalue the role of plants in the environment. This term is not always well-received because of its ableist connotation. MacKenzie et al. (2019) prefered to 'share plant love' to create awareness, while Parsley (2020) created the term 'plant awareness disparity', which aligns closely with the original meaning of plant blindness but suggested that the disparity can be changed through education. The same is true for 'fungus blindness', which was used by Sheldrake (2020). Ignorance of both plants and fungi, however, has been made worse by local and global education systems not giving much coverage to both kingdoms Plantae and Fungi in their curricula. Botany as a degree appears to have not been offered in the UK since at least more than a decade ago (Drea, 2011; UCAS, 2022); instead, botany-related degrees and courses are usually available under the term 'Plant Sciences' (Jose et al., 2019), which may not necessarily include plant taxonomy nor train students with the skills to identify plants (Stroud et al., 2022). The situation is even more dire for Mycology, which was hosted traditionally in Botany departments. Such courses seem to have largely disappeared and only a few universities offer degrees concentrating on pathogenic fungi or plant pathology (e.g., see https://thebiologist.rsb.org.uk/biologist-features/spotlight-on-mycology), which would likely ignore the majority of fungi that provide useful ecosystem services. If students have no prior exposure to plants and fungi in their growing up years and no opportunity to learn about them at the undergraduate level, it is no wonder that they will be 'blind' to plants and fungi in that they underappreciate their values and therefore have little interest in them. The lack of exposure at a younger age may also lead to lower enrolment into universities that do offer Botany degree courses, resulting in fewer researchers working on plants and fungi (Drea, 2011), and few being able to teach about them in the future. These students may eventually become policy makers or leaders in companies who do not value either biological kingdom.

The aim of this paper is to highlight how the teaching of Botany and Mycology has evolved over the years in Singapore, with a focus on tertiary education at the National University of Singapore and to propose actions that are needed to reverse the blindness to both kingdoms.

HISTORICAL BACKGROUND OF HIGHER EDUCATION ON PLANTS AND FUNGI IN SINGAPORE

Early colonial Singapore from the 1800s. When the British first arrived in 1819, the island of Singapore was lush with forests (Corlett, 1992). The rich diversity of flora and fauna was collected by Thomas Stamford Bingley Raffles, Alfred Russel Wallace, Henry Nicholas Ridley, as well as by other naturalists. The collected specimens were sent back to England and eventually ended up in the Museum of the Zoological Society of London (Bastin, 1990) or the herbaria of the Royal Botanic Gardens at Kew for plants and at Edinburgh for fungi. There has been no documentation of any organised education of the local populace about biodiversity under the early colonial government.

From the University of Malaya to the National University of Singapore. In the early 1900s, when the colonial administration and the business community became more established, the main goals of education were to prepare those who could afford to attend schools to become lawyers, doctors, teachers and other professionals to meet the needs of the colony (Goh, 1997). The first medical institution, the Federated Malay States Government Medical School, was established in 1905 and subsequently renamed the King Edward VII College of Medicine (Lee, 2005).

The Raffles College was established in 1928 to provide tertiary education in the arts and sciences. This College was later merged with the King Edward VII College of Medicine in 1949 to become a new entity, the University of Malaya. Two departments dedicated to studying and teaching the natural sciences were formed under the University of Malaya: the Botany Department headed by Professor R.E. Holttum in 1949, and the Zoology Department headed by Professor K.D. Duncan in 1950 (Matsudaira et al., 2017). The Singapore division of the University of Malaya was renamed the University of Singapore, which was eventually merged with the Nanyang University (not to be confused with the Nanyang Technological University of today) to become the National University of Singapore (NUS) in 1980 (Hor et al., 2000).

After the Botany Department was set up in 1949, it actively undertook the teaching and training of local university students, producing Botany graduates who were well versed in tropical plants and fungi. Between 1949 and 1968, Botany was both offered as an undergraduate major subject and taught as a postgraduate course. Undergraduate courses taught under the Botany major were Taxonomy, Anatomy, Physiology, Ecology, Mycology and Cryptogamic Botany. Subjects were taught using local flora and there were field trips to Malayan forests and beaches. Staff and students developed close bonds during those rough-it-out field trips. Class sizes were extremely small: there were only two honours graduates from the founding cohort of ten students, who entered university straight after passing the Senior Cambridge examinations (equivalent to the O-Level examination of today, there was no A-Level examination then) (Lim, 1989).

From 1969 to 1989, the student intake increased and they could graduate with a Bachelor of Science (B.Sc.) degree in three years. The number of students graduating with Honours in Botany ranged from three to seven in the 1960s, eight in the 1970s and 11–16 in the 1980s (Lim, 1989). Botany units were taught together with Zoology units under Biology A (organismal biology of plants and animals) and Biology B (functional and developmental of plants and animals) courses. Plant Taxonomy and Mycology were subsumed under Biology A. Lectures were under an hour but held twice a week and there were practical sessions weekly. Those best performing students in the third-year examinations would be offered a fourth year of study leading to B.Sc. with Honours. Botany, Zoology, Biochemistry, Chemistry, Applied Chemistry, Mathematics, Physics and Physiology were Honours courses.

Many of the Botany graduates were employed by the Singapore Botanic Gardens and the Parks and Recreation Department, the predecessor of the National Parks Board (NParks), where they subsequently assumed senior roles and contributed to the development of Singapore as the Garden City. Other Botany graduates joined the teaching profession where they were able to share their passion and botanical knowledge with generations of school children.

Contemporary organisational and curricular changes. Organisational changes subsequently took place for the Botany Department. In 1996, it merged with the Department of Zoology and formed the School of Biological Sciences. In 1998, this became the Department of Biological Sciences and Botany became a Plant Biology unit within the department.

The emphasis on Botany became further diluted as the scope of undergraduate Biology education at the NUS broadened to include other departments. From 1995, courses became modular. Biology A and Biology B were replaced by Cell and Molecular Biology, Developmental and Systems Biology and Integrative and Organismal Biology. Botany was renamed Plant Biology, with many elective modules such as: Agrobiology, Cell and Molecular Biology, Economic Botany, Genetics (later Molecular Genetics), Horticulture (later Landscape Horticulture), Mycology, Plant Biochemistry, Plant Breeding, Plant Morphogenesis and Tissue Culture, Plant Pathology, Plant Physiology, Plant Systematics and Biogeography, Seed Biology, Tropical Ecology, Vascular Plants and Virology (including plant viruses). Students chose

modules that appealed to them and thus there may have been knowledge gaps. Modules might also have ceased to have been offered owing to a lack of students.

From 2003 onwards, the Plant Biology major and most Botany-related modules were phased out. These included Mycology, Plant Systematics and Biogeography, Plant Pathology, Vascular Plants, Economic Botany, Agrobiology and Seed Biology. The remaining modules were restructured—Plant Physiology was merged with Animal Physiology and renamed General Physiology (and tentatively to be no longer taught from 2023 with the retirement of staff without any replacement). Plant Morphogenesis and Tissue Culture became Plant Growth and Development, and Landscape Horticulture was defunct before being reintroduced in the form of Tropical Horticulture. Plant Physiology was no longer taught as a module on its own after the last lecturer, Dr Ong Bee Lian, passed away in 2015. As the years went by, fewer and fewer plant science modules remained as staff retired without successors. These changes and the reduced emphasis on Botany-related modules impacted how the undergraduates and graduates viewed plants and fungi.

IMPLICATIONS OF PLANT AND FUNGUS BLINDNESS

When General Biology textbooks were written and mainly taught as a course by zoologists or high school teachers in the US, it likely diluted the learning of both Botany and Zoology and later created an imbalance of focus favouring Zoology (Wandersee & Schussler, 1999). Mycology suffers an even worse fate as millions of young people do not know what fungi are and university education is highly inadequate (Moore et al., 2006).

The Botany/Plant Biology curricula in Singapore have changed over the years and this would have strong implications for the education of the young. While these changes followed a global trend to embrace new technologies and frontiers of science and to align with the economic developments of Singapore, they would have also shaped students' perspectives and their views of plants when they become the next generation of teachers, administrators, leaders and policymakers. The lack of exposure to or experience with the living plants (and fungi) when young would shape their impressions years later and they would show scant interest in them (Hershey, 1996). As a result of schooling, upbringing, lack of exposure or awareness, people in Singapore would easily develop 'plant blindness' or 'fungus blindness'.

Blindness to these two kingdoms is detrimental to botanical and mycological literacy, education, and the pursuit for food sustainability, conservation, and sustainable development. An example of botanical illiteracy highlighted by Hershey (1996) was a Science journal paper written by Amato (1993). In it, Amato wrote that *Gingko* produced berries containing nuts. However, berries and nuts are in fact, two mutually exclusive categories of fruits; furthermore, fruits are produced by angiosperms, and not gymnosperms—of which *Gingko* is a member—which produce naked seeds and not fruits. A recent example of mycological illiteracy was displayed in a local news article, which mentioned that scientists from Singapore and Switzerland reported that fungal mycelium is rich in substances such as cellulose and chitin (Begum, 2021). This is a fundamental misconception, as fungi do not have cellulose because they are not plants.

The prevalence of plant and fungus blindness may have impacts on food security as societies may miss out on opportunities to increase food sources using plants and fungi. Although people seem to prefer a meat-based diet, based on food production and import volumes in Singapore (Singapore Food Agency, 2022), plants and fungi are critical for food security and balanced diets. To grow animals and fish for food, a lot of resources such as animal feed, water, antibiotics and land space are needed. Even with plant-based meats being new alternatives, crops such as soy, coconut, chickpeas, and other plant materials are still needed. Therefore, being able to differentiate and breed plants, understand their pests and diseases, and procure sustainable sources of fertilizers such as tapping on mycorrhizal fungi are critical to food production. There appears to be only one fungal-based product (mycoprotein) sold as a meat substitute in Singapore so far under the brand Quorn, but there are several sold elsewhere in the world (Barzee et al., 2021). However, more options should be made available soon, in view of the urgency regarding climate change. With more fungal-based food options, people may be more interested to learn more about fungi and invest in more research and development. Since there are millions of species of fungi, the potential is enormous. On the other hand, annually, over 250 people have died or become sick because they confused toxic plants for edible ones in France and numerous others in Hong Kong were accidentally poisoned by mushrooms (Whitworth, 2019).

Lowered awareness of plants and fungi would also have implications for the conservation of species in these two kingdoms. Even for trained professionals, the setting of conservation policies is made more challenging because of difficulties in surveying and understanding the state of forests, which can range from an untouched primary forest to a human-encroached degraded forest on the other end of the spectrum, with many variations in between (Chazdon et al., 2016). The quality of the regenerated (i.e., secondary) forest is much poorer than the original primary forest in supporting biodiversity (Lennox, 2018). Likewise, people unfamiliar with fungal biology may not know that deforestation reduces the presence of saprophytic fungi in favour of increasing pathogenic species (Shi et. al, 2019); likewise, for mycorrhizal fungi, once the host trees are lost, they, too, will follow suit. According to Balding & William (2016), animal conservation organisations receive more donations than plant conservation work. People outside of the botanical or mycological circles may not know that about 40% of plant species are likely threatened with extinction (Cheek et al., 2020) or may not

understand the lack of resources and challenges in plant conservation. For instance, the demand for agar wood (fungus-infected wood of *Aquilaria* spp., *Gyrinops* spp., *Gonystylus* spp. and *Wikstroemia* spp.) is so high, it is illegally harvested to the point of extinction for some species. Conservation efforts have been too late for some species which have already become globally extinct (Plantations International, 2020).

Increased appreciation for plants and fungi is sorely needed before we lose more forests and natural habitats that these organisms depend upon. Despite years of recognising the problem, environmental sustainability is still elusive (Howes, 2017). While many scientists are concerned about loss of biodiversity and ecosystems (Millennium Ecosystem Assessment, 2005), this does not appear to be the case for those who have much to gain from clearing of forests, including taking the timber, or converting land to cultivate cash crops or for animal husbandry (Lai, 2021). The clearing of forests has not slowed, and soon, what is left behind may not be able to sustain the species remaining. There are too many people, overconsuming natural resources and generating too much waste, pollutants and carbon emissions. Tackling climate change too, cannot have any degree of success without involving the protection of biodiversity (Cannon, 2021). To tackle some of these problems, nature-based solutions such as planting trees have been proposed but they do not always work (The World Bank, 2022). Success is dependent on appropriate tree species selection and understanding plant growth and survival requirements (Long, 2020). Fungi do not appear to have been featured as part of nature-based solutions to date, but they should be: they are crucially important to the health of most plants as they act as living fertiliser, protect them from heavy-metal contaminated soil, pathogens and abiotic stress, and assist in carbon sequestration (Giovannetti, 2006; Khare et al., 2018; Zhang et al., 2018; Malyan et al., 2019). On the flip side, fungi may also be pathogenic to plants, animals or humans and there are not many curative options once disease strikes (Lips, 2016; Arafat et al., 2019; Fones et al., 2020; Olivares et al., 2021). Despite their importance, fungi receive very little research attention (Rodrigues & Nosanchuk, 2020), thus the solutions to many of the problems that plague the world will remain elusive.

SUGGESTIONS FOR THE FUTURE

The trend of plant and fungus blindness in Singapore must be reversed before the experienced botanists and mycologists retire and their knowledge and skills disappear with them. There needs to be opportunities for them to teach the next generation and to pass on their knowledge. They themselves too, must feel the need and urgency to do so and act by passing on their knowledge through writing, or recorded works such as videos. In this context, the limited number of universities that offer Botany and Plant Sciences at the undergraduate level is of concern. Students taking these modules are not likely to learn topics like plant identification, anatomy, or plant diseases in-depth. In recent years, the Department of Biological Sciences at the NUS has improved on the offering of Botany and Mycology-related modules, including Comparative Botany and Fungal Biology, and recently, Vegetation and Plant Diversity of Southeast Asia taught by staff from the National Parks Board, in an attempt to bridge the knowledge gap in Mycology and Botany, but this is still inadequate. Since there are strong concerns about climate change, food security, the conservation of plants, and a boom in interest in gardening and indoor plants owing to Covid-19 (Burke et al., 2022), Economic Botany, Seed Biology, and other topics on the relationship between plants and the environment need to be taught, together with training in thinking, processing and investigative skills (Uno, 2009).

Not everyone is blind to plants or fungi. Some plant scientists or plant enthusiasts developed their interest from their childhood exposure growing up on farms, going on nature walks or through being inspired by teachers (Jose et al., 2019). Singapore does not have many farms but we can start with what we currently have. Teachers can be trained in plant and fungus identifications at the National Institute of Education. More plant and fungus guides or resources can help teachers identify what is found in their schools so that they can teach their students. Educators, starting from pre-school teachers onwards, can bring out the fascinating or useful aspects of plants (Frisch et al., 2010; Pany et al., 2019) and fungi to make the topic relatable to the younger generation of learners and help them overcome the nature deficit disorder which is also related to plant and fungus blindness. Exposing their young charges to the outdoors would also be good for the eyes as it may lower their risk of developing myopia (Turbert, 2020). Teachers can also share stories about plants and the origin of plant names to encourage their young charges to better relate to plants. Relating may be in the form of emotions, whether through awe or unforgettable (pleasant or unpleasant) experiences; may involve use of any of the five senses (auditory, sight, olfactory, tactorial and gustatory); or may be developed through experiential learning (e.g., growing plants in community gardens or within school compounds, small projects such as naming plants in the neighbourhood, taking part in guided field trips, cooking, conducting leaf and stem sectioning, plant pressing, playing plant-related games, taking videos or pictures). Since Singapore is known for its rich cuisines that use a lot of spices and plant materials, and with traditional medicines also strongly linked to the different cultures in Singapore, food and medicines can be an avenue for students to gain an interest in plants and fungi. If students are interested and can comprehend the subject matter, they then will have the motivation for self-learning and further reading (Ainley et al., 2002).

Singapore's education system should include more topics about the biodiversity of plants and fungi that involve the five senses, and this inclusion should start from young, continue through secondary and tertiary education, and to post-university continuing adult education. "Nature on the Way to School" (Lindemann-Matthies, 2006) or something similar can be adapted according to Singapore's context. The topics can be interspersed with abstract concepts already covered

at O-Level (photosynthesis, transport and reproduction) and A-Level (genetics and evolution). The advantage of doing so is that the students will not forget about the physical life forms they learned in primary school. Students also develop a sense of place (Gruenewald, 2003), a connection to the environment that they live in, which could extend to love and care for the estate, the country and a sense of belonging. If students have learnt well, by the time they reach university, they will still have strong recollections. Otherwise, having to teach fundamental concepts in university modules takes time away from higher-order learning and leads to information overload for the students. Learning does not have to stop upon graduation. Continuing education can be at the university or via public education, such as through biodiversity-related events, museum exhibitions or talks. Such hands-on, informal, bite-size sharing sessions are more digestible and easier for the young and old to appreciate (Green News.ie, 2018).

Education and research are critical to creating awareness and an alternative way of harvesting something valuable from the forest without clearing it. This is urgently needed for regions such as Borneo, the Amazon, and Congo Basin that still have significant tracts of primary forests, as these are the last strongholds of biodiversity and carbon sinks (Lewis et al., 2009; Phillips et al., 2017; Qie et al., 2017). Jobs that protect forests or alternative means of livelihood for the poor and the indigenous people are urgently needed so that they can earn a living without resorting to forest clearance to grow cash crops. Corporations like Cargill and Nestle are recognising that they cannot continue to clear huge tracts of forests to expand land to grow cash crops or rear livestock (Tompkins, 2021). In urban Singapore with its significant land use pressures, Environmental Impact Assessments (EIA) before construction will be required before land development (Tan, 2021). However, the pool of local professionals who are key to conducting these assessments with plant surveys are few, and fewer and fewer people are able to identify plants (B. Tan, pers. comm.). Fungi are not even considered in any EIA in Singapore and this, with the exception of Chile (Hawksworth & Lizoň, 2015), also appears to be the case for other countries, including the UK (UK Parliament, 2022).

Again, this reinforces the need to train undergraduates to have botanical and scientific literacy and the ability to identify plants or fungi, as well as increasing undergraduate research opportunities to hone their skills and eventually mastery at the professional level when they join relevant organisations. Singapore must have a local, continually renewed pool of botanists and mycologists to carry out identification work, teaching, research and consultancy if we want to be close to being self-sufficient in environmental management, edible food production and protection, and disease identification and management. Plants and fungi are our lifelines. We cannot afford to lose them and the skills to identify and study them. The urgency cannot be brushed aside.

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