Mushroom surprise

David Moore

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Fungi are neither bacteria nor plants. David Moore dispels some myths and propagates inspiration

"Hands up those who think fungi are plants," asked a pupil at one of our workshops last year. About 15 out of the 170 pupils on a summer school for Year 10 did so; but 150 hands went up when we asked "how many think fungi are bacteria?".

We're used to battling against the mistaken idea that fungi are plants, but it was a shock to find that so many GCSE pupils believe that fungi are bacteria. It's a bigger error than bringing them up to believe that whales are fish; at least whales and fish are in the same biological kingdom.

The problem seems to result from two faults with the national curriculum.

One is that the mention of fungi is restricted almost exclusively to them as decomposers in nutrient recycling. Unfortunately, curriculum specification references to "decomposers" always link fungi and bacteria, with phrases such as "Describe the role of decomposers, such as bacteria and fungi" (OCR GCSE biology and science double award A); "When putrefying (decay) bacteria and fungi break down the waste products from dead animals and plants ammonium compounds are produced" (AQA biology (human) and science double award (co-ordinated)); "Decomposers: The role of bacteria and fungi" (CCEA GCSE science: biology and single award - modular); "Soil bacteria and fungi act as decomposers" (WJEC science biology and double award). This consistent linkage creates a misunderstanding in the minds of many pupils.

The national curriculum does nothing to dispel this because its second, and fundamental, fault is that it ignores the fungal kingdom. Pupils are ignorant about fungi because the national curriculum is ignorant about fungi.

Does it matter? Definitely. Practically, because activities of fungi are crucially important in our everyday lives. Educationally, because fungi form what is arguably the largest kingdom of higher organisms on the planet.

Fungi are not bacteria, because fungi are eukaryotes, with the complex cell structures and abilities to make tissues and organs that we expect of higher organisms. Fungi are a kingdom of higher organisms alongside animals and plants, and awareness and understanding of them ought to be an essential educational goal for even the youngest children since we encounter fungi and their products every day. Teaching biology without teaching about fungi is like trying to teach reading with only two-thirds of the alphabet.

Currently, little fungal biology appears in the national curriculum, which only compares animals with plants. But fungi are not plants; they are so different from plants that no amount of plant biology will give an adequate understanding of any fungus. Similarly, although more closely related, in molecular terms, to animals than to plants, fungi are not animals and a deficiency of fungal biology cannot be compensated by more zoology. Yet none of the GCSE specifications (not even those for GCSE biology) state that fungi are not plants, nor do they state that fungi are higher organisms/eukaryotes.

Kingdom fungi needs to be portrayed as a major eukaryotic kingdom; fungi have their own unique cell biology, biology and lifestyle, and play a crucial role in every ecosystem and food web.

Fungi are not just mushrooms, yeast and moulds. Fungi (known as anaerobic chytrids) digest the grass eaten by cows (and all other herbivores) and by so doing indirectly provide the milk for our breakfast, the steak for dinner and the leather for shoes.

Fungi make plant roots work (more than 95 per cent of all terrestrial plants depend on mycorrhizal fungi) and, even leaving aside the effect of this on the evolution of land plants, by so doing mycorrhizal fungi help provide the corn for our cornflakes, oats for our porridge, potatoes, lettuce, cabbage, peas, celery, herbs, spices, cotton, flax, and timber.

And even oxygen for our breath.

The characteristic fungal lifestyle is the secretion of enzymes into their environment to digest nutrients externally; we harness this feature in our biotechnology to produce enzymes to start our cheese-making, clarify our fruit juices, distress denim for "stone washed" jeans, and, conversely, provide fabric conditioners to repair day-to-day damage to our clothes in the weekly wash.

Fungi also produce a range of compounds to compete with other organisms in their ecosystem; when we harness these for our own purposes we create products like cyclosporin, which prevents organ rejection by suppressing the immune response in transplant patients, the statins, which keep so many people alive by controlling cholesterol levels, and even today's most widely used agricultural fungicides, the strobilurins.

None of these interesting facts appear in any of the current GCSE specifications (not even those for 2006). Instead, we find the same stories about yeast fermentations (bread and alcohol) and the discovery of penicillin. We don't underestimate their importance, but penicillin was discovered in 1928 and industrialised in the mid-1940s.

What can we do about it? Lobbying educational advisors and examining boards hasn't got us far. Indeed, we have a letter from a science advisor for the QCA (March 9, 2005) that states: "I suspect that one reason why many of the interesting points you raise in your letter are not taught or assessed is that teachers and examiners are not aware of them themselves." It appears that it's not only children who need educating.

The British Mycological Society has devised resources to use within the current national curriculum. These have all been successfully classroom-tested with groups of pupils ranging from Year 8 to Year 11.

Individually, they provide for stand-alone lessons: pupil understanding and awareness of fungi can be improved with as little as one to five hours of "fungus-oriented" lessons.

So, if you think fungi are bacteria: you're wrong.

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Lessons in fungi

Cite fungi as a distinct group of organisms different from animals and plants: Key stage 2/science 2: Distinguish between animals, plants and fungi (eukaryotes) and bacteria (prokaryotes).

Key stage 3/science 2 and key stage 4: emphasise differences between animal, plant and fungal cells.

Key stage 4 life processes and living things 1a & b: differences in nutrition characterise the three eukaryotic kingdoms.

Key stage 4 life processes and living things 5d & e: fungi are major contributors to food chains and energy transfer in ecosystems

resources

Work-sheets and classroom materials can be downloaded free from: www.fungi4schools.org'How the Mushroom Got its Spots' is a guide to fungi: www.bbsrc.ac.uk/society/schools/resources/Welcome.htmlwww.fungi4schools.orgThe Fungi Name Trail is a key to common fungi in a foldout chart.Field Studies Council: www.field-studies-council.org/publications 'Fungus Fred goes Foraying' is a story book for seven to 11 year-olds.

These resources will be available from the British Mycological Society on stand C10 at the Association for Science Education conference exhibition, January 5-7

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How much are your children taught about fungi in school?

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Although fungi are fundamentally important in our every day lives, the Kingdom is largely ignored by the National Curriculum in the United Kingdom. Consequently, children are missing out on being taught about a crucially important group of organisms. This paper aims to show the deficiencies in the curriculum specifications in UK primary and secondary schools, and describes a range of British Mycological Society learning resources designed to remedy the situation. These ready-made (and classroom-tested) lessons and workshop sessions cover a range of fungal topics from cell structure and function, through biotechnology to health topics and plant growth and disease. The resources include games and activities, aiming to increase knowledge and awareness of fungi in an active, entertaining way and thereby maintain interest in biology as a science.

Keywords: primary, secondary, school, science, biology, animal, plant, fungi, classroom activities, teaching resources

Introduction

In the United Kingdom, the most likely answer to the question 'How much are your children taught about fungi in school?' is: 'Very little or nothing at all!'

It's a sad truth that there is a distinct lack of fungal biology in the school curriculum although fungi are fundamentally important to virtually every aspect of our every day lives. From the fungi involved in food manufacture – including the chytrids that enable cows to produce meat and dairy products, and the mycorrhizal fungi which provide the essential nutrients for growth of our plants and trees, to those that provide commonly used pharmaceuticals, we depend on fungal activities every hour of every day. Yet the content of the National Curriculum (NC) is a real concern because whilst current specifications all contain material about the animal and plant Kingdoms, there is little or no consideration of the largest group of higher organisms on Earth: Kingdom Fungi. Inevitably, children leave school knowing very little about what is scientifically and commercially an extremely important Kingdom. More importantly, they leave school with a distorted understanding of the living world. This will come as a surprise to parents who might expect science teaching to provide a properly balanced foundation to their children's education and future life.

UK Education Structure

There are four key stages which make up the compulsory education of a child in the United Kingdom. Any further education undertaken after Key Stage 4, for example going on to do A-levels, is the choice of the individual. Primary education comprises Key Stage 1 (age 5-7 years) and Key Stage 2 (age 7-11 years), while secondary education covers Key Stage 3 (age 11-14 years) and Key Stage 4 (age 14-16 years).

During primary education children are taught twelve NC subjects. These are divided into the core subjects, English, Maths, Science and ICT (Information and Communication Technology), and the non-core or foundation subjects, Geography, History, Design Technology, Art, Music, Physical Education, Personal, Social and Health Education (PSHE) and Modern Foreign Languages. Religious Education must also be taught in most primary schools. National tests (SATs) are taken at the end of both primary key stages. Key Stage 1 tests are taken in English and Maths, and Key Stage 2 tests are taken in English, Maths and Science.

At secondary school a similar range of subjects is taught but science is divided into separate components of biology, chemistry and physics. At the end of Key Stage 3, pupils make their choices of which GCSE subjects they wish to follow. At Key Stage 4, it is mandatory for all pupils to take the three core NC subjects at GCSE. These are English (and Welsh in Wales), Science and Mathematics.

The majority of pupils take GCSE examinations at the end of year 11 when most are 16 years old. The minority that do not take GCSEs may follow GNVQs, vocational GCSEs or other national qualifications.

The UK National Curriculum

According to their website (http://www.qca.org.uk/) the Qualifications and Curriculum Authority (QCA) "maintains and develops the national curriculum and associated assessments, tests and examinations; and accredits and monitors qualifications in colleges and at work." They also co-publish (with the Department for Education and Employment) the National Curriculum (NC) programmes.

The word 'fungus' does not appear in the 87-page National Curriculum Programme of Study for Science, which is the statutory instrument that defines the curriculum for Key Stages 1-4 (ages 5 to 16)(The National Curriculum for England: Science (1999)). The same applies to the revised curriculum, which comes into effect in 2006. But it's not just the case that the NC ignores fungi; rather they seem to be actively excluded right across the age range. Throughout the text of the NC, teachers are instructed specifically to compare animals and plants. A few example quotations will suffice to illustrate this.

In Key Stage 1 (KS1), under 'Life processes': "...Pupils should be taught...to relate life processes to animals and plants found in the local environment."

Similarly, in KS2 'Life processes': "Pupils should be taught...to make links between life processes in familiar animals and plants and the environments in which they are found." In 'Variation and classification': "Pupils should be taught: (a) to make and use keys, (b) how locally occurring animals and plants can be identified and assigned to groups, (c) that the variety of plants and animals makes it important to identify them and assign them to groups." Under 'Adaptation' the instruction is to teach "...about the different plants and animals found in different habitats [...and...] how animals and plants in two different habitats are suited to their environment." The closest we get to fungi in KS2 is under 'Micro-organisms' where pupils should be taught "that micro-organisms ...are often too small to be seen, and that they may be beneficial [for example, in the breakdown of waste, in making bread] or harmful [for example, in causing disease, in causing food to go mouldy]."

KS3 continues to ignore Kingdom Fungi, but at this stage, although pupils should "... consider key factors that need to be taken into account when collecting evidence..." teachers are still instructed, under 'Cells and cell functions' to teach "...that animal and plant cells can form tissues, and tissues can form organs... and ... the functions of chloroplasts and cell walls in plant cells and the functions of the cell membrane, cytoplasm and nucleus in both plant and animal...". The "key factor" that fungi rightly belong somewhere within that paragraph has evidently not been collected.

And so it goes on into KS4 and towards GCSE, the NC instructs that in Single Science (GCSE examinations taken by about 74,000 pupils in 2004): "1. Pupils should be taught: to relate ways in which animals function as organisms to cell structure and activity." In Double Award Science (GCSE examinations taken by over one million pupils in 2004), the instruction for Cell activity is that: "1. Pupils should be taught: (a) about similarities and differences in structure between plant and animal cells; (b) how substances enter and leave cells through the cell membrane by diffusion, osmosis and active transport; (c) that the nucleus contains chromosomes that carry the genes; (d) how cells divide by mitosis during growth, and by meiosis to produce gametes; (e) to relate ways in which animals and plants function as organisms to cell structure and activity." This paragraph excludes fungi despite the enormous proportion of current knowledge that depended on research work with fungi.

Implementation of the National Curriculum

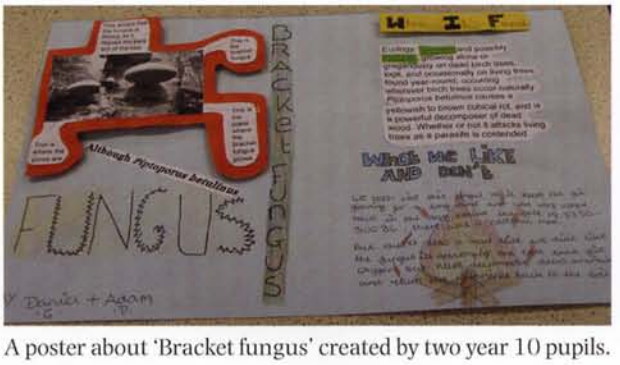
By defining the content of the examinations, it is the Examination Boards that determine the detailed content of lessons in UK schools. Examination of their curricula reveals how much representation fungi are likely to get in what is taught in today's schools. There are five Examination Boards that offer GCSEs in the United Kingdom: Assessment and Qualifications Alliance (AQA), Council for the Curriculum, Examinations and Assessments (CCEA), Educational Excellence (EDEXCEL), Oxford Cambridge and RSA Examinations (OCR) and Welsh Joint Education Committee (WJEC). CCEA is a Northern Ireland examining board and WJEC is a Welsh examining board, the other three are English. England, Northern Ireland, Scotland and Wales all have different National Curriculum Programmes. The Scottish Qualifications Authority (SQA) is the national body in Scotland responsible for the development, accreditation,


Teaching the 'Cells' package after a 'DNA workshop' in Manchester Museum.


Teaching the 'Cells' package – up close and personal.


A year 10 class in an inner-city school in Manchester uses the Internet to find their favourite (or least-favourite) fungus ....


...and then enjoys creating a poster about it.



A poster about 'Bracket fungus' created by two year 10 pupils.


Mushroom structure can be taught with shop bought mushrooms but can lead into ideas about developmental biology, biodiversity, food science and commerce.


Pupils, especially girls, need to be encouraged to enjoy science and see its relevance to their everyday life.


The 'What's your favourite fungus?' card school at a British Association Science Week event in Manchester. Strictly scientific! But strictly fun, too!

assessment and certification of qualifications other than degrees; with Learning and Teaching Scotland (LTS) as the executive public body sponsored by the Scottish Executive Education Department to help review, assess and support developments in learning and education. We have not examined the Scottish curricula.

The different Examination Boards publish different curriculum specifications, but have a broadly similar examination structure. Pupils that take the science subjects separately obtain three GCSEs, one each for biology, chemistry and physics. About 4% of candidates attempted the separate Biology GCSE in 2004 (and approximately the same percentage attempted Chemistry and Physics as separate topics). The curriculum for each GCSE in these cases is more detailed than either single or double awards. In Single Award Science the three science subjects are incorporated into one GCSE qualification (although three examination papers are taken), but the academic content is reduced for each science. About 6% of candidates attempted the Science Single Award in 2004. The Double Award Science is by far the most popular (82% of pupils taking the examinations in 2004) and comprises three individual papers of chemistry, biology and physics; successful candidates receive two GCSE grades of the same level. Whether the qualification is stated as being modular or non-modular indicates how the course is assessed. Non-modular, also known as linear, is when there are no mid-term examinations; all examination papers are sat at the end of the year. In the modular structure, examinations are taken at the end of each module, so there are mid-term examinations taken before the whole specification has been taught.

For the minority of pupils who take the separate Biology GCSE course, fungi are represented reasonably well in the curriculum specifications issued by all Examination Boards. For most single award Science curricula, on the other hand, there is no mention of fungi at all, with the exception of its role as a decomposer in the specification given by the CCEA. Apart from Salters (OCR) and Modular (AQA), all Double Awards do have fungi represented in the curriculum specification, but the content is very limited and unimaginative.

An important point is that none of the specifications (not even those for GCSE Biology) state that fungi are not plants, nor do they state that fungi are higher organisms/eukaryotes. How can pupils be taught biology without clear, simple definitions properly distinguishing the different sorts of organisms that exist on this planet? This is a major failure in the education system, but it gets worse, because some of the statements about fungi in the curriculum specifications are incorrect! Fungi are said to have saprophytic nutrition in the 2004 CCEA GCSE Biology specification, and the 2004 WJEC Biology specification states confidently that "moulds consist of a mass of fine threads called hyphae which are not subdivided into cells."

Although, as we've stated, fungi tend to be reasonably well treated in GCSE Biology specifications, in the courses followed by the overwhelming majority of schoolchildren (the Double Award specifications taken by 82% in 2004) mention of fungi is restricted almost exclusively to them being decomposers in the carbon and nitrogen cycles. Sadly, beneath every silver lining there's a black cloud. In this case, it is unfortunate that specification references to 'decomposers' always link fungi and bacteria, with phrases such as "Describe the role of decomposers, such as bacteria and fungi..." (OCR GCSE Biology and Science Double Award A); "When putrefying (decay) bacteria and fungi break down the waste products from dead animals and plants ammonium compounds are produced..." (AQA Biology (Human) and Science Double Award (co-ordinated)); "Decomposers: The role of bacteria and fungi..." (CCEA GCSE Science: Biology and Single Award (modular)); "Soil bacteria and fungi act as decomposers..." (WJEC Science Biology and Double Award). We fear that this conjunction produces a misunderstanding in the minds of many pupils. At a Summer School for year 10 pupils recently, we asked the pupils before our workshop sessions "Are fungi plants, animals, bacteria or none of these?" Responses from the 21 pupils in our teaching session comprised two who chose plants; two 'none of these' and 17 chose bacteria. This disturbing outcome was reinforced when all attendees (approximately 170 pupils) were asked "Hands up all those who think fungi are plants", about 15 hands went up. When they were asked "Hands up all those who think fungi are bacteria", at least 150 hands went up. Whatever efforts teachers might be making to describe the activities of bacteria and fungi, they are clearly not distinguishing between these organisms; but then, the NC does not require them to do so!

Missed opportunities in the National Curriculum

The conclusion from this analysis is that fungi are not represented in the school-work of the vast majority of schoolchildren. For those who are taught something about fungal biology, the material is insufficient to make the basic biological distinction between fungi and bacteria. Only a very small minority of pupils are given

Information sources

Assessment and Qualifications Alliance (AQA) (2004) Curricula accessible via www.aqa.org.uk/.

CCEA, General Certificate of Education in Biology, Northern Ireland Council for the Curriculum, Examinations & Assessment. Curricula accessible via www.ccea.org.uk/.

Department for Education and Skills. (2004) GCSE results. Crown copyright 1995-2004. Accessible via www.dfes.gov.uk.

Edexcel GCSE in Biology Specification. Edexcel Foundation 2000. Curricula accessible via www.edexcel.org.uk/home/.

Learning and Teaching Scotland is an executive non-departmental public body sponsored by the Scottish Executive Education Department to help review, assess and support developments in learning and education. The LTS website is at http://www.ltscotland.org.uk/index.asp.

Oxford, Cambridge and RSA Examinations Publications. (2001) *Curricula* accessible via www.ocr.org.uk.

National Curriculum Online is at this URL: http://www.nc.uk.net/. For every subject, this site shows the programmes of study and non-statutory guidelines; attainment targets and notes and links to online teaching resources.

ParentsCentre is a DfES-developed website giving a wide range of information about children and learning: www.parentscentre.gov.uk/.

Scottish Qualifications Authority is at http://www.sqa.org.uk/sqa/.

Teachernet (developed by the Department of Education and Skills as a resource to support the teaching profession) www.teachernet.gov.uk/educationoverview/uksystem/structure

The National Curriculum for England: Science (1999). Jointly published by Department for Education and Employment & Qualifications and Curriculum Authority (document QCA99/461). Also available from the website www.qca.org.uk.

Welsh Joint Education Committee. (2004) Curricula accessible via www.wjec.co.uk.

BMS teaching resources, integrated under the general title *Key Stages for Fungi*, can be obtained by requesting them from David Moore, Faculty of Life Sciences, 1.800 Stopford Building, The University of Manchester, Manchester M13 9PT.

what might be considered a properly representative amount of information.

Clearly, it doesn't have to be like this. Readers of *Mycologist* will be well aware, from what we have described so far, that there are many missed opportunities where fungi could be incorporated into the school curriculum, either as a study in their own right, or serving as examples or illustrations of other scientific points in the curriculum.

Kingdom Fungi needs to be portrayed as a major eukaryotic Kingdom; fungi are not plants, they are not bacteria, and post-16 is too late to leave such a basic piece of information about the nature of the organisms that surround pupils in their everyday lives. Sadly, those who composed the current GCSE specifications seem content to persist with the Victorian obsession of comparing animals with plants. Fungi have their own unique cell biology, their own unique developmental biology, their own unique life style, and a crucial place in every ecosystem and in every food web on this planet. They form the third great Kingdom of eukaryotic organisms, arguably larger than plants and animals combined. Is that not enough to get them proper representation in the NC?

Despite their lack of representation in the NC, with a little bit of thought, fungi can be used for teaching many areas of the current curriculum specifications and in cross-curricular activities. Fungi are not just mushrooms, yeast and moulds.

- Fungi digest the grass eaten by cows (and all other herbivores) and by so doing indirectly provide the milk for our breakfast and the steak for dinner and the leather for shoes.
- Fungi make plant roots work (more than 95% of all terrestrial plants depend on mycorrhizal fungi) and, even leaving aside the effect of this on the evolution of land plants, by so doing mycorrhizal fungi help provide the corn for our cornflakes, oats for our porridge, potatoes, lettuce, cabbage, peas, celery, herbs, spices, cotton, flax, timber, etc. And even oxygen for our daily breath.
- The characteristic fungal life style is the secretion of enzymes into their environment to digest nutrients externally; and we harness this feature in our biotechnology to produce enzymes to start our cheese-making, clarify our fruit juices, distress denim for 'stone washed' jeans, and, conversely, provide fabric conditioners to repair day-to-day damage to our clothes in the weekly wash.
- Fungi also produce a range of compounds to compete with other organisms in their ecosystem; when we harness these for our own purposes we create products like cyclosporin, which prevents organ rejection by suppressing the immune response in transplant patients, the statins, which keep so many people alive these days by controlling cholesterol levels, and even today's most widely used agricultural fungicides, the strobilurins.

We can't expect teachers to be aware of these interesting facts as none of them appear in any of the current GCSE specifications (not even those due to come into effect in 2006). Instead, we find, at best, the same old stories about yeast fermentations (bread and alcohol) and the discovery of penicillin. We don't underestimate the importance of these aspects of fungal biotechnology, but penicillin was discovered in 1928 and industrialised in the mid-1940s. How many other aspects of today's Science curriculum are so firmly embedded in what must be seen as 'the distant past' by the pupils?

What can we do about it?

We have tried lobbying educational advisors at examining boards and higher authorities by letter but we're not convinced that this will lead to much change (and remember that the revised NC that comes into effect in 2006 is just as dismissive of fungi as is the current one). Some of the examining boards failed to respond, while others sent seemingly helpful initial responses, but then failed to follow up in any way.

But the most dismaying response was from a Science Advisor for the QCA, who stated (letter dated 9 March 2005), and we quote: "I suspect that one reason why many of the interesting points you raise in your letter are not taught or assessed is that teachers and examiners are not aware of them themselves." Remember that the QCA, in their own words, "maintains and develops the national curriculum", so we are not reassured that fungal biology is in good hands if the QCA is so willing to admit to the complete ignorance of its teachers and examiners. It is not only the children that need educating!

If the QCA cannot be entrusted with it, then the British Mycological Society will have to take up the challenge. For several years the Society has been developing educational enhancements, and we have recently taken a more systematic approach to this. The premise is that it should be possible to devise resources that teachers will be willing to use within the current NC because they address NC topics, and we can ensure that they give proper representation to fungi.

During the past year we have produced a range of teaching resources that are fully portable, adaptable and available. These include:

- an integrated set of class sheets, quizzes and question sheets dealing with cells and cell biology, which, of course, ensure proper representation of both yeast and filamentous fungus.
- a series of five ready-made KS4 lessons comprising an introductory *Welcome to the World of Fungi, Reproduction and Conservation, Favourite or Nastiest Fungus, Fungi and Industry* and *Fungi and Disease*. All of these lesson packages include class sheets for both pupil and teacher, the latter including references to supplementary materials carefully chosen from articles previously published in British Mycological Society publications.
- an integrated series of class sheets that describe 10

different 'What's your favourite fungus?' stories from which the pupils extract important points, a pack of playing cards that mirror the class sheets and can be used to play a variety of games (and all the time the players are holding cards that each carry a different 'fungal fact'), a 'name-game' starter exercise and an extensive set of word search puzzles related to the class sheets.

These materials have all been class-room tested with groups of pupils ranging from year 8 through to year 11 and these sessions were evaluated with our own quizzes and questionnaires issued both before and after the main activity intended to assess the pupils' learning during the session as well as their reactions to the material. The resources were all well received by the pupils and successfully increased their knowledge base. Individually they provide for standalone lessons and by so doing they make the point that in asking for more representation of fungi in the curriculum we are not asking for a large slice of teaching time to be allocated to mycology. These resources, and the experience we have had with them, show that pupil understanding and pupil awareness of fungi can be improved with as little as one to five hours of 'fungus-oriented' lessons.

However, the resources are highly adaptable, allowing the teacher to include parts of them in other lessons. They can be mixed in a variety of ways and also work well as a Science Week-style special event or when used for the 'theoretical' background for a workshop featuring some practical activity (school foray, food science investigation, industrial visit, etc.).

These resources have been integrated into a package that is available for distribution (free) from the British Mycological Society (address below). At present our resources are aimed at Key Stage 4, but we are working with the University of Manchester's Children's University project to adapt this (and other) material to suit KS2.

The current materials furnish the tools to teach a class about fungi in a completely balanced, timely and interesting way. We hope that they will be taken up by teachers, but they are also useful to academics who might want to offer Science Week events, and to Local Fungus Groups who wish to broaden the teaching at their forays or offer fungus-centred sessions to their local schools.

We are working on how to distribute the materials to teachers and are working towards an integrated package presented on CD, but for the moment we seek the assistance of readers of *Mycologist*. Bring their existence to the attention of teachers in your local schools. Use them to offer workshops or Science Week sessions for your local schools. If you are interested in fungi then you have to take on the responsibility for spreading your enthusiasm.

If mycologists do not offer this sort of remedial teaching about fungi, no one else will. If nobody offers teaching about fungi our schools will continue to produce well-educated people who think that fungi are bacteria, and are quite content with their ignorance.

We thank the British Mycological Society, the Biotechnology and Biological Sciences Research Council, and the Business, Careers and Community Division of the University of Manchester for grants and sponsorship that enabled the work reported here to be undertaken. Sincere thanks are also due to Margaret Whalley, Louise Sutherland, Vicky Caldwell, Barbara Grundy and Karen Bolshaw for their help in devising, delivering and describing the teaching resources.

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journal homepage: www.elsevier.com/locate/mycres

Mycological Research News[1]

This month *Mycological Research* News features: In this issue; and Crisis in teaching future generations about fungi.

Twelve papers are included in this part, of which five concern *Peronosporomycetes*: A 400 My old Early Devonian new fossil genus; *Plasmopara* species on *Geraniaceae*; A new genus for *Bremia graminicola*; Asexual recombination in *P. halstedii*; and a Novel approach to the microarray detection of *Phytophthora* species.

Other papers address: Powdery mildews on *Catalpa*; Effects of novel antifungal pyrazoles on *Magnaporthe grisea*; dsRNA viruses in *Chalara elegans*; Population structure of *Armillaria* species at the landscape scale; Effects of hypersaline conditions on *Trimmatostroma* species; Effects of water potential on *Rhizoctonia solani* from potato; and Community structure of ectomycorrhizal fungi in wooded meadows.

The following new scientific names are introduced: *Graminivora,* and *Hassiella* gens. nov.; *G. graminicola* (syn. *Bremia graminicola*) comb. nov.; and *H. monospora, Plasmopara geranii,* and *P. praetermissa* spp. nov.

In this issue

This issue includes a series of papers on different aspects of *Peronosporomycetes* (syn. *Oomycetes*), the members of which are classified in the kindgom *Chromista* or *Straminipila* in modern classifications, and not in the kingdom *Fungi*. These fungus-like organisms, that have traditionally been and continue to be studied by mycologists, include some of the most destructive plant pathogens known (e.g. *Phytophthora* spp.). Little is known of their early evolutionary history, but now a new fossil has been discovered in 400 My old Early Devonian Rhynie Chert deposits from Scotland which has features suggesting it had antheridia and oogonia/oosporangia, all well-illustrated in the paper (pp. 628-632). It is therefore clear that the oomycetes did not evolve very recently, as had been hypothesized by Tom Cavalier-Smith.

Molecular phlyogenetic studies on two groups of plant pathogenic oomycetes are presented. Five species of *Plasmopara* parasitic on *Geraniaceae* are recognized, all forming highly supported monophyletic lineages, and two proved to be new; detailed descriptions, nomenclatural data, illustrations, and a key are provided (pp. 633-645). *Bremia graminicola,* which occurs on subtropical and tropical *Arthraxon* grasses, has unique features in the genus and was the only one to occur on grasses; molecular and morphological data now show that it is not related to other *Bremia* species, but is a sister group to *Viennotia,* and a new generic name is therefore introduced to accommodate it (pp. 646-656).

In *Plasmopara halstedii,* which attacks sunflower, inoculation experiments with field isolates and single sporangium lines differing in host preference and fungicide sensitivity led to the production of asexually formed zoosporangia; these produced a new phenotype combining features of the parental strains which was stable over many generations, and demonstrate the occurrence of parasexuality in this fungus (pp. 657-663). Finally, a novel method for the differentiation of *Phytophthora* species using duplex melting kinetics and microarrays is described; it is shown to be effective in the detection of individual and mixtures of species more robustly than traditional approaches (pp. 664-671).

Four papers concern other plant pathogens. A detailed study combining morphological and ITS sequence analysis revealed that three species of powdery mildews occurred on *Catalpa* in the UK in 2004; the newly reported *Neoerysiphe galeopsidis* appeared first in the year, but was soon out-competed by *Erysiphe elevata* which has recently spread into Europe from the USA (pp. 672-686). The effectivity of a range of newly synthesized pyrazoles at different doses against the causal agent of rice blast, *Magnaporthe grisea*, is assessed; a cyclohexyl or *n*-butyl group generally increased antifungal activity, the most active causing ultrastructural damage to the endomembrane system (pp. 687-697). An investigation of double-stranded RNA elements in *Chalara elegans* (synam. *Thielaviopsis basicola*), which causes black root rot in several important crops, revealed that these carried at least three groups of viruses, with two clones showing no homology to any previously known virus group (pp. 698-705). A detailed study of *Armillaria* populations in a Swiss *Pinus mugo* forest, using somatic incompatibility tests, showed that while *A. cepistipes* and *A. borealis* genets occupied modest areas (mean 0.2 ha and 0.6 ha respectively), *A. ostoyae* (mean 6.8 ha) genets could occupy as much as 37 ha (pp. 706-713).

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Two black yeast species from extreme environments, *Trimmatostroma salinum* (hypersaline) and *T. abietis* (from a marble monument), are compared with respect to effects of salinity at the colony and ultrastructural levels; both were able to adapt to hypersaline conditions but responded in different ways (pp. 714-725). The effects of different water potentials on *Rhizoctonia solani* anastomosis groups 2-1 and 3 from potato are investigated for the first time; growth generally and sclerotial germination was reduced with decreased osmotic potential, and differences were found between the behaviour of the different anastomosis groups (pp. 726-734).

The diversity of ectomycorrhizal fungi from managed and unmanaged wooded meadows in Estonia has been examined using a combination of the morphology of the ectomycorrhizas on root tips and direct sequencing; 172 species were detected, and there were differences between the communities present in the two woodland types (pp. 735-749).

Crisis in teaching future generations about fungi

Readers of *Mycological Research* will be well aware that mycology has never been as important as it is today, and that this is an exciting time to be studying the enormous diversity, functions, and roles of fungi. We know that fungi play essential roles in the environment, in human nutrition and health, and serve as indispensable model organisms in basic biological research. We might expect that our biological colleagues were equally aware of these facts, and that any educational presentation of ''biology'' would include a balanced description of prokaryotes (bacteria and archea), eukaryotic protists, and fungal, animal, and plant biology. After all, leave out any of these components and the story of life on Earth is incomplete and defective. But when your children walk into school, do you know what the developers of the school curriculum have decided they should be taught? What we know about school curricula in our countries implies that most children get an incomplete and defective story of life on Earth in school because fungi are simply not included in the curriculum. How can we foster an interest in fungi if generations of schoolchildren are kept in ignorance of them? The purpose of this note is to ask mycologists around the world to study their school curricula and tell us what the situation is like in their countries.

It is evident, for example, that in the UK, the academics who developed the National Curriculum do not know much about fungi. Children in the UK, from primary level onwards, are taught about bacteria, animals, and plants. No fungi. In England alone, more than one million children each year complete their statutory National Curriculum with no knowledge of kingdom *Fungi* (Moore *et al*. 2005).

The situation seems to be similar elsewhere in the world. Many of the points made by Moore *et al*. (2005) are also relevant to the education system in schools in Australia. In Austria and Germany, secondary schools have the freedom to modify their curricula and develop their own specific profiles. These schools should provide pupils with standard entry qualifications for university, but in biology, which is one of their core subjects, fungi are marginalized or totally ignored. Likewise in Argentina, in the normal certificate of education (up to 14 years old), biology is incorporated into natural sciences together with chemistry and physics, and fungi are not considered. Courses leading to a technical or agricultural bachillerato include more biology, but fungi are included to the extent they deserve in only a few schools belonging to national universities.

In the USA, individual states (and sometimes even individual school districts) dictate the content of their science curricula, and there are examples of schoolteachers who do give their students a good grounding in mycology. However, the National Science Education Standards that act as a benchmark for the whole country (http://newton.nap.edu/html/nses/) provide a search engine on their website and this finds only one line containing the string 'fung*' in the entire text. That line reads, ''Decomposers, primarily bacteria and fungi, are consumers that use waste materials and dead organisms for food.'' This detail is depressingly similar to the UK National Curriculum, which also, when it mentions fungi at all, brackets bacteria and fungi together, and thereby breeds ignorante. Returns of a recent questionnaire show that over 80 % of 15-16-year olds in Manchester think that fungi are bacteria.

Also alarming is that mycological education is inadequate at most universities. At university, because of the decline of organismal biology and rise of systems biology, the best we can expect is that some yeast molecular biology will survive the narrowing focus on medical and biotechnological topics in both teaching and research. However, that hundreds of thousands of university students are not being taught enough about fungi is not the real problem. The fundamental crisis is that *many millions* of school children are not being taught anything about fungi.

It is vital that we get awareness of fungi into schools, from primary through to secondary education, to banish the cosy, comfortable notion that complex organisms are either animals or plants. If this could be accomplished, then the process of improvement would become self-driving. Sixteen-year-olds who know what fungi are and how fungi affect their daily lives, will expect to learn more in pre-university courses. University entrants who know a balanced amount of fungal biology will expect the same balance in their university courses. In time, graduates with a good education in the whole of biology will become university teachers and then the teaching of animal, plant *and fungal* biology will be a natural part of a good scientific education.

It's a heady vision that will take time to achieve. Indeed, it may require a revolution in school curriculum design; and not many mycologists are involved in school curriculum design. But mycologists can make a contribution towards turning the tide of ignorance. Experience in the UK is that schoolteachers are willing to include fungi in their teaching if they are provided with the resources to do so. The teacher's concern is to teach the curriculum specified by their national authority. Schoolteachers do not have the time, or indeed the knowledge, to devise ways to use fungi to illustrate the statutory curriculum. Yet there are many aspects of science (and not just biology) that can be illustrated with fungal examples, and who is better placed to identify these than the committed mycologist? There are already several books for the general reader that provide a good starting point, which should at least be recommended to (and maybe even gifted to) school libraries, and some more classroom-oriented resources have been produced by the British Mycological Society and the Royal Botanic Gardens Melbourne[2].

Most of the school teaching resources that are available are in English, but we doubt that limitation of statutory school biology to animals, plants and bacteria is unique to the English-speaking world. This is one reason why we want information about school curricula around the world – in how many languages should the resources be produced? The second reason we want information from you is to get you involved. Mycologists around the world *must* become involved in communicating their science to schoolchildren unless they're willing to see their science wither. So our questions to you are these: do your school curricula call for comparisons only between animals and plants? Do they offer details about animal and plant cells only? Do they only ever mention fungi (and always linked with bacteria) as 'decomposers' or 'degraders'? Do most of the 16 year-olds in your country think that fungi are some kind of bacteria? These are the symptoms of the disease afflicting the national curricula in our countries. Do you recognise them? If you do, then please contact the first or another of the authors.

Moore D , Fryer K , Quinn C , Roberts S , Townley R , 2005. How much are your children taught about fungi in school? *Mycologist* **19**: 152–158.

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2 For suggested books and available teaching resources see http://www.fungi4schools.org and http://britmycolsoc.org.uk.