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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

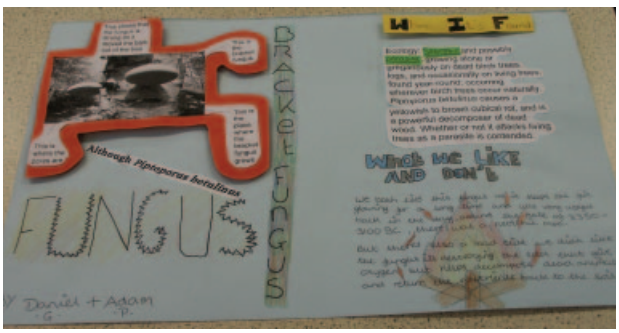
By defining the content of the examinations, it is the Examination Boards that determine the detailed content of lessons in UK schools. Examination of their curricula reveals how much representation fungi are likely to get in what is taught in today's schools. There are five Examination Boards that offer 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.

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