*Biology> Big idea BHD: Health and disease > Topic BHD3: Health and infectious disease*

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| **Key concept (age 11-14)** |
| **BHD3.1: Pathogens** |

**What’s the big idea?**

A big idea in biology is that organisms must stay in good health to survive and thrive; the health of an individual organism results from interactions between the organism’s body, behaviour, environment and other organisms.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by exploring the idea that the health of humans, other animals and plants can be affected by diseases caused by infection with pathogens, including viruses and some bacteria and fungi.

The conceptual progression starts by checking students’ prior understanding of the idea that ‘germs’ are disease-causing microorganisms, and that these pathogens cause some but not all diseases. It then supports the development of the ideas that not all microorganisms cause ill health, how pathogens cause symptoms, and that pathogens do not cause symptoms of ill health until they are present in sufficient numbers.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Pathogens**

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| **Learning focus** | The health of humans, other animals and plants can be affected by infection with pathogens, including viruses and some bacteria and fungi. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Recall that ‘germs’ are disease-causing microorganisms also known as pathogens, including bacteria, fungi and viruses.  **P** | Recall that pathogens cause some but not all diseases in humans, other animals and plants.  **P** | Recognise that not all microorganisms cause ill health. | Explain simply how pathogens cause symptoms of ill health. | Apply the idea that pathogens do not cause symptoms of ill health until they are present in sufficient numbers.  **B** |
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| **Diagnostic questions** | Timmy’s tummy ‘bug’ | Causes of disease | Yogurt drink | Sam’s symptoms | Food poisoning |
| ‘Germs’ | Attack of the pathogens! |
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| **Response**  **activities** | What do bacteria look like? | Plant disease detectives | Microorganisms on trial! | The hole story | Divide and conquer |
| Pathogens | |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Timmy’s tummy ‘bug’** | **‘Germs’** | **Causes of disease** | **Attack of the pathogens!** | **Yogurt drink** |
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| Drawing | Confidence grid | Simple multiple choice | Simple multiple choice | Confidence grid |
| **Sam’s symptoms** | **Food poisoning** |  |  |  |
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| Talking heads,  simple multiple choice | Two-tier multiple choice |  |  |  |

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| **What do bacteria look like?** | **Pathogens** | **Plant disease detectives** | **Microorganisms on trial!** | **The hole story** |
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| Discussion,  critiquing a representation | Discussion, talking heads | Fieldwork | Role play, discussion | Discussion, card sort |
| **Divide and conquer** |  |  |  |  |
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| Application and practice |  |  |  |  |

**What’s the science story?**

The health of an organism can range from good to ill. The health of an individual organism results from interactions between the organism’s body, behaviour, environment and other organisms.

The health of humans, other animals and plants can be affected by diseases caused by infection by pathogens, including viruses, and some bacteria and fungi. Pathogens are usually too small to be seen without a microscope. Microorganisms are present on and in the human body all the time; most are not pathogens, and some form part of our defences against pathogens. Symptoms of disease appear when the body’s cells or systems have been damaged or are not working normally. An organism may not always show symptoms after infection with a pathogen; pathogens only cause symptoms when they are present in sufficient numbers.

**What does the research say?**

*Learning about health*

The school curriculum has an important role to play in developing health literacy (IUHPE, 2010; Paakkari and Paakkari, 2012; Kilgour et al., 2015; Bruselius-Jensen, Bonde and Christensen, 2017). Research has shown that the development of health literacy in children is important in reducing the incidence of disease (e.g. Hanson and Gluckman, 2011), and that efforts to improve the health literacy of school children can have impacts on their behaviour (e.g. Park et al., 2017). Research suggests that young children’s primary source of health information is their family, television, public health campaigns, and also teachers and friends at school (Maxted, 1984; Brindal et al., 2012); children’s personal experiences of disease also affect their conceptions of it (Prokop, Fancovicová and Krajcovicová, 2016). What students learn about microorganisms (often specifically pathogens) from their family, their peers and the media predates and often contrasts with what they learn in school (Bandiera, 2007). Hence, children at age 11 are likely to have many preconceptions about health and disease from everyday life.

*Learning about infectious disease*

In England, the National Curriculum expects pupils to learn about “the importance of hygiene for humans” at age 5-7 (Department for Education, 2013), but ideas about pathogens (disease-causing microorganisms) and communicable (infectious) disease are not required to be explored further until age 14-16 (Department for Education, 2015). Extensive curriculum development work undertaken by the Royal Society of Biology in the UK (McLeod, 2018) and the American Association for the Advancement of Science (AAAS Project 2061, 2009) recommends that students should learn about germ theory and infectious disease in science lessons from the beginning of their primary school education, and develop their understanding at each stage thereafter.

When asked about “healthiness”, children up to age 12 primarily equated the term with eating a healthy diet and being physically active (Hesketh et al., 2005; Protudjer et al., 2010). When children aged 5-9 in Australia (Brindal et al., 2012), 9-11 in the US (Reeve and Bell, 2009) and 14-15 in Turkey (Çetin et al., 2013) were asked to draw and write about healthy and unhealthy things, most of the students’ answers related to food and drink (over 60% in the US study) and physical activity. When asked to draw and write about “disease” (Isik, Çetin and Özarslan, 2017), children aged 14-15 in Turkey referenced the following as causes of disease: microbes [58% of answers in which a cause was mentioned], malnutrition [15%], cigarettes and alcohol [11%], and dirty environment [9%]. Similar results were observed when children aged 8-11 in Hungary were asked to draw and write about causes of disease (Piko and Bak, 2006).

Only one student out of 81 in the Turkish study made reference to plants – by drawing a “faded flower” that was said to be “sick”; all other answers pertained to humans. Learning about plant diseases is important due to the interdependence of organisms; for example, plant disease has a significant impact on human food security. It has been estimated that plant pests and pathogens are responsible for approximately 12.5% of global crop losses (Oerke, 2006), and for losses of up to 42% of the annual production of the six most important food crops (Guest, 2012). A focus only on communicable diseases that affect humans provides an undesirably restricted view, and could lead to (or reinforce) the misunderstanding that only humans get diseases.

*Terminology*

In a study of students aged 12-13 in England, the terms ‘microorganism’ and ‘microbe’ were not used spontaneously to describe organisms such as bacteria that are too small to see with the unaided eye; the term ‘germ’ was most commonly used, followed by ‘bug’ (Maxted, 1984).

The term ‘germ’ is often used indiscriminately without understanding of the existence of (or differences between) separate types of disease-causing microorganisms such as bacteria and viruses. Furthermore, the common and incorrect practice of referring to *all* microorganisms as ‘germs’ indicates the misunderstanding that all microorganisms cause disease (Byrne and Sharp, 2006); most bacteria and fungi are not pathogenic, and many have beneficial and important roles (see Guidance notes, below).

In everyday language, the term ‘bug’ is often used indiscriminately to refer to microorganisms as well as to insects (e.g. flies) and arthropods such as arachnids (e.g. spiders), myriapods (e.g. centipedes and millipedes) and crustaceans (e.g. woodlice) (Shepardson, 2002; Allen, 2014).

Students often refer to ‘bacteria’ without distinction between the singular (‘bacterium’) and plural (‘bacteria’) forms (Driver et al., 1994).

*Pathogens*

In a classic study of British and American children aged 5-11, all participants referred to a single type of ‘germ’ and were unaware that different diseases are caused by different pathogens (Nagy, 1953). Half of the English 12-13 year-olds in Maxted’s study (1984) suggested that different types of ‘germs’ caused different diseases, while only 9% of students aged 15 in a study in England by Prout (1985) knew that bacteria and viruses were different types of disease-causing agents.

When the children in Nagy’s study were asked to draw what they thought ‘germs’ look like, half of the 5-7 year-olds drew nothing. Older children drew dots, stars and representations similar to insects and spiders – apparently conflating different types of ‘bugs’, or perhaps not appreciating the difference between pathogens and some of the animal vectors that carry them. Similar depictions of bacteria have been reported in more recent studies involving students’ drawings (Prokop et al., 2016; Haşiloğlu and Eminoğlu, 2017). Depictions of microorganisms as insects or spiders also reveals misunderstandings about what cells look like, their size and scale (Arnold, 1983), of the differences between unicellular and multicellular organisms, and indicates the prevalence of animistic and anthropomorphic views such as that cells can have limbs or faces (Dreyfus and Jungwirth, 1988; Byrne et al., 2009).

Barenholz and Tamir (1987) found that students aged 15-17 could not adequately explain how microorganisms cause symptoms of disease; although they held some correct rudimentary notions such as that microorganisms inside the human body would breed and ‘poison us’, they also held animistic and anthropomorphic views such as that they would ‘walk about’ and ‘eat us’. The students thought that microorganisms would mainly enter the human body through the mouth, but also recognised that they could enter through the nose and skin.

**Guidance notes**

Bacteria and other microorganisms are often portrayed in everyday life and even in lessons in a negative light, particularly in disease contexts; this likely contributes to widespread negative perceptions of microorganisms, and to concerns that many students (and teachers) have about working with living microorganisms in lessons (Lock, 1996); it also underscores the need for positive approaches to reassure students that most microorganisms are not harmful (Lock, 2011).

In a study of concept maps drawn by 169 students, Byrne & Grace (2010) found that 11-year-olds much more readily associate microorganisms with disease and the spoilage of food than with any useful roles. In a subsequent study of concept mapping, drawing and interviews with 458 students, Byrne (2011) found that negative perceptions of microorganisms were present in students of all ages from 7-14. In a study of 836 primary school students, over half described microorganisms as being harmful, dirty or a form of pollution (Karadon and Şahin, 2010).

The materials developed for this key concept use the scientific term ‘pathogen’ (rather than the everyday term ‘germ’) to refer specifically to microorganisms that cause disease. The indiscriminate labelling of all microorganisms as ‘germs’ or ‘bugs’ (or even as ‘pathogens’) could reinforce negative attitudes towards them. Although this key concept focusses on pathogens, care should be taken in lessons to avoid creating or reinforcing the common misunderstanding that *all* microorganisms cause disease; it will be helpful to positively reinforce the message that most bacteria and fungi are not pathogenic, and that many have beneficial and important roles (e.g. the breakdown and cycling of substances by decomposers, and the roles of the gut microbiota in supporting digestion and nutrition).

**References**

AAAS Project 2061. (2009). *Benchmarks for Science Literacy* [Online]. Available at: <http://www.project2061.org/publications/bsl/online/index.php>.

Allen, M. (2014). *Misconceptions in Primary Science, 2nd* ednBerkshire, UK: Open University Press.

Arnold, B. (1983). Beware the molecell! *Biology Newsletter,* 42**,** 2-6.

Bandiera, M. (2007). Micro-organisms: everyday knowledge predates and contrasts with school knowledge. In Pintó, R. & Couso, D. (eds.) *Contributions from Science Education Research.* Berlin: Springer.

Barenholz, H. and Tamir, P. (1987). The design, implementation and evaluation of a microbiology course with special reference to misconceptions and concept maps. In Novak, J. D. (ed.) *Proceedings of the 2nd International Seminar: Misconceptions and Educational Strategies in Science and Mathematics, 26-29 July.* Ithaca, N.Y.: Cornell University.

Brindal, E., et al. (2012). How do Australian junior primary school children perceive the concepts of "healthy" and "unhealthy"? *Health Education,* 112(5)**,** 406-420.

Bruselius-Jensen, M., Bonde, A. H. and Christensen, J. H. (2017). Promoting health literacy in the classroom. *Health Education Journal,* 76(2)**,** 156-168.

Byrne, J. (2011). Models of micro-organisms: children's knowledge and understanding of micro-organisms from 7 to 14 years old. *International Journal of Science Education,* 33**,** 1927-1961.

Byrne, J., et al. (2009). Children's anthropomorphic and anthropocentric ideas about micro-organisms. United Kingdom.

Byrne, J., Grace, M. and Jenny Byrne and Marcus, G. (2010). Using a concept mapping tool with a photograph association technique (CoMPAT) to elicit children's ideas about microbial activity. United Kingdom.

Byrne, J. and Sharp, J. (2006). Children's ideas about micro-organisms. *School Science Review,* 88(322)**,** 71-80.

Department for Education (2013). *Science programmes of study: key stages 1 and 2 - National curriculum in England (DFE-00182-2013),* London, UK.

Department for Education (2015). *Biology, chemistry and physics GCSE subject content (DFE-00352-2014),* London, UK.

Dreyfus, A. and Jungwirth, E. (1988). The cell concept of 10th graders: curricular expectations and reality. *International Journal of Science Education,* 10(2)**,** 221-229.

Driver, R., et al. (1994). *Making Sense of Secondary Science: Research into Children's Ideas,* London, UK: Routledge.

Guest, D. (2012). The impact of plant disease on food security. *Agriculture,* 2(Special Issue).

Hanson, M. and Gluckman, P. (2011). Developmental origins of noncommunicable disease: population and public health implications. *The American Journal of Clinical Nutrition,* 94**,** 1754S-1758S.

Haşiloğlu, M. A. and Eminoğlu, S. (2017). Identifying cell-related misconceptions among fifth graders and removing misconceptions using a microscope. *Universal Journal of Educational Research,* 5**,** 42-50.

Hesketh, K., et al. (2005). Healthy eating, activity and obesity prevention: a qualitative study of parent and child perceptions in Australia. *Health Promotion International,* 20(1)**,** 19-26.

Isik, E., Çetin, G. and Özarslan, M. (2017). Students' views about disease concept: drawing and writing technique. *Asia-Pacific Forum on Science Learning and Teaching,* 18(2).

IUHPE. (2010). *Promoting Health in Schools: From evidence to Action* [Online]. International Union for Health Promotion and Education. Available at: <https://www.iuhpe.org/images/PUBLICATIONS/THEMATIC/HPS/Evidence-Action_ENG.pdf>.

Karadon, H. D. and Şahin, N. (2010). Primary school students’ basic knowledge, opinions and risk perceptions about microorganisms. *Procedia Social and Behavioral Sciences,* 2(2)**,** 4398-4401.

Kilgour, L., et al. (2015). Health literacy in schools: prioritising health and well-being issues through the curriculum. *Sport, Education and Society,* 20(4)**,** 485-500.

Lock, R. (1996). Educating the "New Pasteur". *School Science Review,* 78**,** 63-72.

Lock, R. (2011). Microbiology and biotechnology. In Reiss, M. (ed.) *Teaching Secondary Biology.* 2nd ed. London, UK: Hodder Education.

Maxted, M. A. (1984). *Pupils' prior beliefs about bacteria and science processes: their interplay in school science laboratory work.* MA, University of British Columbia, Canada.

McLeod, L. (2018). Developing a framework for the biology curriculum. *School Science Review,* 100(370)**,** 23-29.

Nagy, M. H. (1953). The representation of "germs" by children. *Journal of Genetic Psychology,* 83**,** 227-240.

Oerke, E. C. (2006). Crop losses to pests. *The Journal of Agricultural Science,* 144(1)**,** 31-43.

Paakkari, L. and Paakkari, O. (2012). Health literacy as a learning outcome in schools. *Health Education,* 112(2)**,** 133-152.

Park, A., et al. (2017). Associations between health literacy and health behaviors among urban high school students. *Journal of School Health,* 87(12)**,** 885-893.

Piko, B. F. and Bak, J. (2006). Children’s perceptions of health and illness: images and lay concepts in preadolescence. *Health Education Research, Theory and Practice,* 21(5)**,** 643-653.

Prokop, P., Fancovicová, J. and Krajcovicová, A. (2016). Alternative conceptions about micro-organisms are influenced by experiences with disease in children. *Journal of Biological Education,* 50(1)**,** 61-72.

Protudjer, J. L. P., et al. (2010). Children’s perceptions of healthful eating and physical activity. *Canadian Journal of Dietetic Practice and Research,* 71(1)**,** 19-23.

Prout, A. (1985). Science, health and everyday knowledge: a case study about the common cold. *European Journal of Science Education,* 7(4)**,** 399-406.

Reeve, S. and Bell, P. (2009). Children's self-documentation and understanding of the concepts 'healthy' and 'unhealthy'. *International Journal of Science Education,* 31(14)**,** 1953-1974.

Shepardson, D. P. (2002). Bugs, butterflies, and spiders: children's understanding about insects. *International Journal of Science Education,* 24(6)**,** 627-644.

Çetin, G., et al. (2013). Students' views about health concept by drawing and writing technique. *Energy Education Science and Technology Part B: Social and Educational Studies,* 5(1).