*Biology> Big idea BCL: The cellular basis of life > Topic BCL2: From cells to organ systems*

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| **Key concept (age 11-14)** |
| **BCL2.3: The human skeleton and muscles** |

**What’s the big idea?**

A big idea in biology is that organisms are made of one or more cells, which need a supply of energy and molecules to carry out life processes.

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

This key concept helps to develop the big idea by building understanding that our bones and muscles are important tissues that work together with organs in organ systems to support the life processes of cells to keep us alive.

The conceptual progression starts by checking understanding of the presence and functions of the skeleton and muscles in humans. It then supports the development of understanding of how muscles work, and of the presence and roles of muscles in interacting organ systems that keep us alive.

**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: The human skeleton and muscles**

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| **Learning focus** | Bones and muscles are tissues that work together with organs in organ systems  to support the life processes of cells to keep organisms alive. | | | | |
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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 the human body contains a skeleton and muscles for support, protection and movement.  **P** | Recall that bones and muscles are living tissues made up of cells. | Recognise that muscles, including antagonistic muscles, move bones by contracting. | Explain the presence and roles of muscles in organs and organ systems. | Explain why heart rate increases when we exercise. |
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| **Diagnostic questions** | Without bones | Are muscles and bones alive? | Biceps and triceps | Moving through the digestive system | Exercise |
| Breathing |
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| **Response**  **activities** | Standing up |  | Muscle fuel | Muscles in organ systems |  |
| Visualising muscles and joints |

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

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| **Without bones** | **Are muscles and bones alive?** | **Biceps and triceps** | **Moving through the digestive system** | **Breathing** |
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| Confidence grid, linking ideas | Two-tier multiple choice | Confidence grid | Simple multiple choice | Ordering/sequencing |
| **Exercise** | **Standing up** | **Muscle fuel** | **Visualising muscles and joints** | **Muscles in organ systems** |
|  |  |  |  |  |
| Confidence grid | Challenge to thinking, discussion | Predict, explain, observe, explain (PEOE) | Discussion, modelling | Critiquing a representation, discussion |

**What’s the science story?**

To stay alive, cells need a constant supply of energy and molecules for chemical reactions, and they need to get rid of waste. In a multicellular organism the cells are organised into tissues, organs and organ systems that work together to support the life processes of cells to keep the organism alive.

Humans and other animals have a skeleton and muscles, which are types of tissue made up of cells. Bones provide support and protection for organs. Bones and muscles work together to enable humans to move around, and muscles have vital roles in organs and organ systems.

**What does the research say?**

By age 11, students should know from science lessons that the bodies of humans and other animals have different parts with specific functions, including bones and muscles (AAAS Project 2061, 2009; Department for Education, 2013). Young children may think of the human body holistically as a single entity, but by age 10 they more commonly understand that it has different functional parts that work together to maintain life (Carey, 1985; Driver et al., 1994). Children at this age could also begin to explore some basic ideas that introduce a systems view of life (Capra and Luisi, 2014), including the idea that living systems are organised at different levels (molecules, cells, tissues, organs, organs systems and whole organisms) and that life is a property that emerges from the interactions between the parts that make up these different levels (Skinner, 2011).

Several studies have found that children up to age 20 struggle to appreciate that individual bones are not isolated but are connected to make a functional skeleton (Guichard, 1995; Tunnicliffe and Reiss, 1999). While young children only recognise the supportive and protective (static) functions of the skeleton, older children understand that the skeleton is necessary for movement; however, only one fifth of the older children in one study could draw muscles correctly across a joint (Caravita et al., 1988). Use of real muscles and bones, e.g. raw chicken legs, and models can help children to understand this more effectively, including the idea that muscles can only pull (Haddad, 1995; Goodwyn and Salm, 2007; Fullick, 2011).

It is a common misunderstanding amongst people of all ages that bone (even when it is inside a living organism) is dead, perhaps because bones and skeletons are often associated with imagery of death and with specimens in museums etc.; this misunderstanding is reinforced by the fact that bones are usually only seen when they are outside the body, and are usually only alive when they are inside it (Caravita and Falchetti, 2005; Fullick, 2011). Caravita and Falchetti found that growth and movement were the criteria most commonly applied by students to decide whether bones were alive, as well as phenomenological criteria drawn from personal experience such as that bones hurt when injured and repair when broken; few 8-9 years olds mentioned that bones are made of cells, but it was more common in 12-13 year olds.

A number of studies have used students’ drawings to probe their understanding of what is inside the human body. When children up to age 15 were asked to draw what is inside the human body, most drew organs but very few drew muscles, and when muscles were drawn they were commonly only depicted in the limbs (Reiss et al., 2002; Bartoszeck, Machado and Amann-Gainotti, 2011). Driver’s review of the research literature suggested that there was no evidence that school-age children recognise the involvement of muscles in the digestive, circulatory and respiratory systems (Driver et al., 1994). Several studies have found that children from ages 4 to 10 do not appreciate that food is pushed through the digestive tract by waves of muscle contraction (peristalsis), believing instead that gravity and body movements such as walking and bending are responsible (Teixeira, 2000; AHİ, 2017).

Some children believe that muscles need ‘air’ (rather than oxygen) to work; related misconceptions are that the heart pumps air around the body instead of or in addition to blood, and that the heart rate increases during exercise so that the heart can pump more air to the muscles (Allen, 2014).

**References**

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

AHİ, B. (2017). Thinking about digestive system in early childhood: a comparative study about biological knowledge. *Cogent Education,* 4(1).

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

Bartoszeck, A. B., Machado, D. Z. and Amann-Gainotti, M. (2011). Graphic representation of organs and organ systems: psychological view and developmental patterns. *EURASIA Journal of Mathematics, Science & Technology Education,* 7(1)**,** 41-51.

Capra, F. and Luisi, P. L. (2014). *The Systems View of Life,* Cambridge, UK: Cambridge University Press.

Caravita, S. and Falchetti, E. (2005). Are bones alive? *Journal of Biological Education,* 39(4)**,** 163-170.

Caravita, S., et al. (1988). Investigating pupils' conceptualization in the biological domain: structure-function relationsships. In Duit, R., Saeljoe, R. (ed.) *Students' conceptions of subject matter content. Proceedings of a symposium at the 2.Eur. Conf. for Research on Learning and Instruction, Tuebingen, Sept. 1987.* Kiel: IPN Reports-in-Brief.

Carey, S. (1985). *Conceptual change in childhood,* Cambridge, Massachusetts: Massachusetts Institute of Technology Press.

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

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

Fullick, A. (2011). Gas exchange, movement and fitness. In Reiss, M. (ed.) *ASE Science Practice: Teaching Secondary Biology.* 2nd ed. London, UK: Hodder Education.

Goodwyn, L. and Salm, S. (2007). Modeling muscles. *Science Teacher,* 74(9)**,** 49-52.

Guichard, J. (1995). Designing tools to develop the conception of learners. *International Journal of Science Education,* 17(2)**,** 243-253.

Haddad, R. (1995). Teaching about muscles: are your students flexing their minds as they extend their knowledge? *American Biology Teacher,* 57**,** 178-80.

Reiss, M. J., et al. (2002). An international study of young peoples' drawings of what is inside themselves. *Journal of Biological Education,* 36(2)**,** 58-64.

Skinner, N. (2011). Cells and life processes. In Reiss, M. (ed.) *ASE Science Practice: Teaching Secondary Biology.* London, UK: Hodder Education.

Teixeira, F. M. (2000). What happens to the food we eat? Children's conceptions of the structure and function of the digestive system. *International Journal of Science Education,* 22(5)**,** 507-520.

Tunnicliffe, S. D. and Reiss, M. J. (1999). Students´ understanding about animal skeletons. *International Journal of Science Education,* 21(11)**,** 1187-1200.