

The core concepts of physiology: What are they and how do we know if our students understand them?

J.A. Michael, Department of Molecular Biophysics and Physiology, Rush Medical College, 1750 W. Harrison Street, Chicago, IL 60612, USA.

Core concepts are “big ideas” or general models that provide organizing frameworks for a discipline. Core concepts provide teachers with a powerful tool for organizing their discipline and students with valuable tools for learning that discipline.

In an interactive process involving more than 60 physiology teachers, we have generated a list of 15 core concepts of physiology (Michael *et al.*, 2009; Michael & McFarland, 2011). This group of colleagues also provided us with a rank ordering of the importance of these core concepts. The three most important core concepts for this group of physiologists are homeostasis, cell membrane, and cell-cell communications (the 15 concepts and their rankings follow).

Causality (14)	Cell-cell communications (3)
Cell membrane (1)	Cell theory (9)
Energy (6)	Evolution (15)
Flow down gradients (5)	Genes to proteins (11)
Homeostasis (1)	Interdependence (4)
Levels of organization (12)	Mass balance (13)
Physics/chemistry (10)	Scientific reasoning (8)
Structure/function (7)	

It is important to note several things about this list. (1) This set of concepts is intended to provide a tool to facilitate learning; it is not aimed at organizing research in the discipline. (2) These core concepts are not discrete entities and they overlap with one another in many ways; for example, homeostasis encompasses ideas that also underlie cell-cell communications. (3) There is no single correct list of core concepts.

One goal of our core concepts in physiology project is the development of conceptual assessment instruments with which to determine whether our students understand the core concepts (independent of whether they have mastered the full content of their physiology course).

Because core concepts are big ideas it is difficult, if not impossible, to directly test students' understanding of them. Thus, having identified the core concepts, we next began the process of unpacking them. Unpacking is a process of systematically listing the component ideas that make up the core concept. The result of this process is a conceptual framework. We began by generating the conceptual framework for the concept of homeostasis, again with input from a group of physiology teachers (McFarland *et al.*, in preparation).

Given the homeostasis conceptual framework, we next developed a 20 question multiple choice assessment on the key ideas that make up this core concept (McFarland *et al.*, 2014; McFarland *et al.*, 2015). A cohort of physiology teachers from across the country vetted this concept inventory. It was then administered to over 670 students. An analysis of the results supports several conclusions. The questions are not biased in favor of native English speakers, and there is no gender bias. The questions have varying levels of difficulty and discrimination. Finally, performance on the inventory is related to the amount of physiology that students taking it have had.

The homeostasis concept inventory that has been developed can be used to assess students' conceptual understanding of homeostasis. It can also be used to reveal and address student misconceptions. Finally it can be used as a tool to evaluate the effectiveness of different teaching and learning paradigms.

- McFarland J, Michael J, Wenderoth MP, Modell H, Wright A, Cliff W (2014) Conceptual assessment of physiology: development of a concept inventory for homeostasis. *FASEB J* **28**: 531.13.
- McFarland J, Wenderoth MP, Michael J, Modell H, Wright A, Cliff W. (2015) A homeostasis concept inventory for undergraduate physiology. *FASEB J* **29**: 541.533
- McFarland J, Wenderoth MP, Michael J, Cliff W, Wright A, Modell H. (under review) A conceptual framework for homeostasis: Development and validation. *Adv Physiol Educ*.
- Michael J, Modell H, McFarland J, Cliff W. (2009) The “core principles” of physiology: What should students understand? *Adv Physiol Educ* **33**: 10-16
- Michael J, McFarland J. (2011) The core principles (“big ideas”) of physiology: results of faculty surveys. *Adv Physiol Educ* **35**: 336-341.