

The core principles (big ideas) of physiology: results of faculty surveys



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Abstract:

Physiology faculty at a wide range of institutions (2-year colleges to medical schools) were surveyed to determine what core principles of physiology they want their students to understand. From the results of the first survey a list of 15 core principles was identified. In a second survey respondents were asked to rank order these 15 core principles and, independently, to identify the most important for their students to understand. The five most important core principles were identified as being: "cell membrane," "homeostasis," "cell-to-cell communications," "interdependence," and "flow down gradients." We then "unpacked" the "flow down gradients" core principle to yield the component ideas of which it is comprised. This unpacking was sent to respondents who were asked to identify the importance of each of the component ideas. Respondents strongly agreed with the importance of the component ideas we had identified. We will be using the responses to our surveys as we begin the development of a conceptual assessment of physiology (CAP) instrument (i.e., a concept inventory).

Introduction:

Three NSF-sponsored Conceptual Assessment in Biology (CAB) were held in 2007 (CAB I), 2008 (CAB II) and 2010 (CAB III). CAB I resulted in agreement on 8 core principles applicable to biological sciences (Michael, 2007). Later Michael, Modell, McFarland, and Cliff (2009) described 9 core principles in physiology. Before publication of this paper, we (Michael and McFarland) sought to determine what the community of physiology teachers thought were the most important core principles of physiology by asking them directly.

Methods:

Three Surveys using SurveyMonkey.com were open for one month each.

First survey: Identify the "Big Ideas"/Core Concepts in physiology

Participants were solicited from listservs sponsored by the

- American Physiological Society, Teaching Section
- International Union of Physiological Sciences, Teaching Commission
- Northwest Biology Instructor's Organization
- Human Anatomy & Physiology Society

They were asked to "describe the BIG IDEAS that you would want your students to understand".

The surveys were not anonymous. Respondents to the 2nd and 3rd surveys were solicited from the respondents to the 1st survey. The 2nd and 3rd surveys used Likert scales. Aggregate scores were calculated: the ratings (1 to 5) were multiplied by the number of respondents that selected that rating to give the aggregate score.

Second survey: Rank the Core Concepts identified in the first survey

Third survey: "Unpack" the Core Concept of "Flow Down Gradients"

Survey Respondents:

Table 1: The faculty responding to our surveys teach physiology at a variety of different kinds of academic institutions.

	Survey 1	Survey 2	Survey 3
TOTAL number of respondents	81	61	37
Types of institutions represented*			
A. 2-year community college	24	17	11
B. 4-year college granting only a BS/BA	5	5	1
C. 4-year college/university w/graduate degrees	23	19	9
D. research university	17	14	7
E. professional school (medical/dental/nursing)	29	21	10

*Some faculty teach in more than one institution & were in more than one category

Results:

81 physiology faculty teaching at a variety of institutions (Table 1) responded to this survey and 73 of these responses answered the question with responses that could be interpreted (some respondents left this field blank or listed lecture titles or chapter headings). These 73 useable responses varied in length from a few words to 286 words and there were 7 responses in excess of 150 words.

15 core principles were identified by the physiology faculty that responded to our first survey (Table 2). In the second survey, the respondents to the first survey were asked to evaluate the importance of each core principle (using a 5-point Likert scale). Responses were obtained from 61 of the 81 respondents to the first survey.

Table 2: Core principles proposed by physiology faculty respondents

Core Principle	Rank	Top 5
¹ One of the big ideas identified at the CAB I meeting (Michael 2007)		
² One of Modell's (2000) general models		
³ One of the core principles in Michael, Modell, McFarland and Cliff (2009)		
Causality ^{1,3} Living organisms are causal mechanisms (machines) whose functions are explainable by a description of the cause-and-effect relationships that are present.	14	
Cell-cell communications ² The function of the organism requires that cells pass information to one another to coordinate their activities. These processes include endocrine and neural signaling.	3	X
Cell membrane ² Plasma membranes are complex structures that determine what substances enter/leave the cell. They are essential for cell signaling, transport, & other processes.	1	X
Cell theory ^{1,3} All cells making up the organism have the same DNA. Cells have many common functions, but also many specialized functions that are required by the organism.	9	
Energy ^{1,3} The life of the organism requires the constant expenditure of energy. The acquisition, transformation & transportation of energy is a crucial function of the body.	6	
Evolution ^{1,3} The mechanisms of evolution act at many levels of organization and result in adaptive changes that have produced the extant relationships between structure and function.	15	
Flow down gradients ^{2,3} The transport of "stuff" (ions, molecules, blood, air) is a central process at all levels of organization in the organism and this transport is described by a simple model.	5	X
Genes to proteins The genes (DNA) of every organism code for the synthesis of proteins (including enzymes). The functions of every cell are determined by the genes that are expressed.	11	
Homeostasis ^{1,2,3} The internal environment of the organism is actively maintained constant by the function of cells, tissues, and organs organized in negative feedback systems.	1	X
Interdependence Cells, tissues, organs, and organ systems interact with one another (are dependent on the function of one another) to sustain life.	4	X
Levels of organization ^{1,3} Understanding physiological functions requires understanding the behavior at every level of organization: from the molecular to the social.	12	
Mass balance The contents of any system or compartment in a system is determined by the inputs to and the outputs from that system or compartment.	13	
Physics/chemistry The functions of living organisms are explainable by the application of the laws of physics and chemistry.	10	
Scientific reasoning Physiology is a science. Our understanding of the functions of the body arises from the application of the scientific method, thus our understanding is always tentative.	8	
Structure/function ^{1,3} The function of a cell, tissue or organ is determined by its form. Structure and function (from the molecular level to the organ system level) are intrinsically related to each other.	7	

Responses from faculty teaching at 2-year community colleges and the other respondents teaching at 4-year or graduate institutions were compared. Table 6 shows the rank order of the top 7 core principles. Although the absolute ordering is not identical, there is no clear difference between the two groups about what is important for students to understand.

Table 3: A comparison of the rankings of core principles by community college faculty and all other faculty

Community college faculty (N=17)		All other faculty (N=44)	
Core principle	Ranking	Core principle	Ranking
Homeostasis	1	Cell membrane	1
Interdependence	2	Homeostasis	2
Cell-cell communications	2	Flow down gradients	3
Cell membrane	3	Cell-cell communications	3
Flow down gradients	4	Interdependence	4
Energy	4	Energy	5
Cell theory	4	Scientific reasoning	6

Respondents to the second survey were contacted via email to participate in the third survey (January, 2010). Respondents were asked to indicate whether each of our proposed component ideas that we had unpacked from the core principle of "flow down gradients" was important for their students to understand (using a 5-point Likert scale). 39 of the respondents to the 2nd survey responded to the 3rd survey (Table 1).

The results (Table 4) suggest that our unpacking of this core principle is acceptable to the physiology faculty who responded. Written comments were received from 30 of the 39 respondents. These comments were universally supportive of our unpacking and some contained minor suggestions for rewording, but the respondents did not suggest substantial changes our proposed unpacking.

Table 4: In the third survey, for each item below, we asked faculty to respond to the question "How important is it that your students understand this?"

FLOW DOWN GRADIENTS	Sum of ratings*
I. Flow is the movement of "stuff" from one point in a system to another point in the system	174
A. Molecules and ions in solution move from one point to somewhere else	172
B. Fluids (blood, chime) and gases (air) move from one point to another	154
C. Heat moves from one place to another	131
II. Flow occurs because of the existence of an energy gradient between two points in the system	174
A. Differences in concentration (concentration gradients) cause of molecules and ions in solution to move toward a region of lower concentration	177
B. Differences in electrical potential (potential gradients) causes ions in solution to move	175
C. Differences in pressure (pressure gradients) between two points in a system cause substances to move toward a region of lower pressure	173
D. Differences in temperature (temperature gradients) between two points cause heat to flow	148
III. The magnitude of the flow is a direct function of the magnitude of the energy gradient that is present – the larger the gradient the greater the flow	171
IV. More than one gradient may determine the magnitude and direction of the flow	167
A. Osmotic (concentration gradient) and hydrostatic pressures together determine flow across capillary walls	170
B. Concentration gradients and electrical gradients determine ion flow through channels in cell membranes of neurons and muscle cells	171
V. There is resistance or opposition to flow in all systems	165
A. Resistance and flow are reciprocally related, the greater the resistance the smaller the flow	165
B. Resistance is determined by the physical properties of a system	159
C. Some resistances are variable and can be actively controlled	163
i. Ion channels in a membrane can open & close (increasing resistance)	168
ii. arterioles and bronchioles can constrict and dilate	171
iii. piloerection can increase the resistance to heat flow in many mammals	111

* The number of responses was 36, so the maximum possible sum was 180

Conclusions:

- There is broad consensus regarding core principles in physiology that are consistent with those in the broader discipline of biology.
- Interdependence as a core principle reflects an important agenda of most physiology faculty, that students learn to think "outside the box" of the individual chapters of their textbooks.
- Identification of core principles and their "unpacking" into their component parts will permit us to generate an instrument for conceptual assessment for physiology, i.e. a physiology concept inventory
- Our goal is to unpack the three more core principles (homeostasis, cell-cell communication and cell membranes) and to assemble a concept inventory for these four core principles in physiology in the next two years.

References:

- Michael, J. (2007). Conceptual Assessment in the Biological Sciences: a National Science Foundation-sponsored workshop. *Advances in Physiology Education*, 31: 389-391.
- Michael, J., Modell, H., McFarland, J., and Cliff, W. (2009). The "core principles" of physiology: what should students understand? *Advances in Physiology Education*, 33: 10-16
- Modell, H. I. (2000). How help students understand physiology? Emphasize general models. *Advances in Physiology Education*, 23: 100-107.