

Additional Materials for

A Conceptual Framework for Homeostasis: Development and Validation
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Additional Materials Table 1. Detailed Timeline of the Development of the Homeostasis Conceptual Framework (HCF)

The development of a validated homeostasis conceptual framework involved the use of physiology ‘experts’ in a quasi-Delphi approach. The “Concept Assessment of Physiology” (CAP) team of six physiology faculty evaluated and reached consensus on the repeated revisions of the homeostasis conceptual framework. Versions of the framework were also validated with feedback from faculty survey respondents, workshop participants and discussions during presentations at the Experimental Biology (EB), Human Anatomy & Physiology Society (HAPS) and Northwest Biology Instructors (NWBio) annual meetings.

The HCF (the final validated conceptual framework) in Figure 1 of this paper has been renumbered. During the development of the framework Roman Numerals were used to number the critical components and capitol letters were used to label the constituent ideas in HCF-1 through HCF-3. This system has been used in the supplemental materials to clearly distinguish between the early stages of the framework and the validated version.

Time Frame	Participants	HCF Version	Framework Development & Participant’s Roles
Summer-Fall 2011	Project Team	HCF-1	Team ‘unpacked’ Homeostasis into constituent ideas, creating a conceptual framework for this core concept. This first framework (HCF-1) was the basis for the first survey (October 2011).
Fall 2011-	Survey Respondents		Survey 1. 38 faculty indicated whether each of our proposed constituent ideas of HCF-1 was important for their students to understand (using 5-point Likert scale, from “not important” to “essential”) & commented (open-ended) on language, omissions, etc. ¹
Winter 2012	Project Team		Revised HCF-1 based on results from survey 1 to create HCF-2.
Spring 2012	Conference Participants	HCF-2	Shared outline of HCF-2 at APS annual meeting at EB 2012 in an APS poster session (>10 participants) . Discussed homeostasis misconceptions and shared HCF-2 at NW Biology (~20 participants) and HAPS (40 participants) annual meetings.
Summer-Fall	Project Team		Revised-2 of the framework based on feedback from

Summer-Fall 2012	Project Team		Revised-2 of the framework based on feedback from conference and meeting participants to create HCF-3.
Fall 2012	Project Team		Evaluated 11 undergraduate textbooks for terms used in presentation of homeostatic processes
Winter 2013	Survey Respondents	HCF-3	Survey 2. 16 faculty to assessed importance ² and difficulty ³ (5-point Likert scale) of proposed constituent ideas of HCF-3 (December 2012-January 2012).
Spring 2013	Conference Participants		Shared parts of the HCF-3 at APS annual meeting at EB 2013 at an APS symposium (~50 attendees) and at workshops at NW Biology and HAPS annual meetings included 20-30 faculty at 2 workshops.
August 2013	Project Team	HCF	Discussed, edited and produced the final revision of

Additional Materials Table 2. Undergraduate Textbooks used to evaluate the use of terms regarding homeostasis

We evaluated the following ten textbooks in 2012 to answer a number of questions, including “to what extent are the same terms [regarding homeostasis] used in different textbooks” (28). We selected 2 or 3 commonly used textbooks that cover human or animal physiology in four types of undergraduate courses. We assessed the use of the following terms: negative feedback (used in 8 or 10 textbooks), set point (10 of 10), control center (6 of 10), integrator (3 of 10) and others.

Textbooks used in courses for

Anatomy & Physiology (200-level, 2-term sequence)

Human Anatomy & Physiology, Ninth Edition, by Marieb & Hoehn
Fundamentals of Anatomy & Physiology, Ninth Edition, by Martini & Nath
Principles of Anatomy and Physiology, 13th Edition, by Tortora & Derrickson

Human Physiology (200-level, one term)

Human Physiology: An Integrated Approach, Sixth Edition by Silverthorn
Human Physiology: From Cells to Systems, Eighth Edition, by Sherwood

Introductory Biology (200-level, majors sequence, 3 quarters or 2 semesters)

Campbell: Biology, Ninth Edition, by Reece, *et al.*
Biological Science, Fourth Edition, by Freeman
Life: The Science of Biology, Ninth Edition, by Sadava, *et al.*

Animal Physiology (300-level, one term)

Animal Physiology, Third Edition, Hill, Wyse, & Anderson
Eckert Animal Physiology, Fifth Edition, by Randall, Burggren, & French

Additional Materials Table 3. “Importance” Survey Data from October 2011 (HCF-1)

These data are from the October 2011 survey of physiology. Forty faculty responded to the survey and there were 38 responses that included usable Likert responses. Two faculty completed 0-50% of the Likert questions). A few respondents omitted responses to a few questions and their responses were used, yielding 35-38 responses per item.

Conceptual Framework (October 2011 draft)	not important				essential
I. The organism maintains a more or less stable internal environment	0	0	0	3	35
---A. The organism’s internal environment differs from its external environment.	0	0	4	9	25
---B. The external environmental variables may change.	0	0	4	13	21
---C. As the external environment changes, homeostatic processes maintain a more or less stable internal environment.	0	0	0	9	29
---D. Many variables of the internal environment are maintained stable in order to sustain cell function.	0	0	2	7	29
---E. Only a limited number of physiological variables are regulated (i.e. held more or less stable)	1	4	13	14	5
II. A substantial change to a regulated variable will result in a physiological response to restore it toward to its normal range	0	0	1	5	31
---A. The regulated variable is usually held stable by a negative feedback system	0	0	2	6	30
---B. The process of homeostasis requires a sensor, a control center (which contains an integrator/comparator & manipulator) and an effector or effectors (That is, the process of homeostasis requires the components of a negative feedback system.)	0	0	0	7	31
---C. In most instances the compensatory response can only partially correct the disturbance to the regulated variable	0	2	10	19	6
III. Homeostatic processes require a sensor (“what can’t be measured can’t be regulated”.)	0	0	1	5	31
---A. Sensors detect the regulated variable and respond by transducing that stimulus into a different physiological signal	0	3	4	8	23
---B. A physiological system may employ a variety of types of sensory receptors	0	0	2	18	18
---C. Sensory receptors may be in different, distant locations in the body	0	4	7	16	11
IV. Homeostatic processes require a control center	0	0	2	4	31
---A. The control center includes an integrator/comparator and a manipulator	0	3	5	16	14
---B. The integrator/comparator receives a signal from the sensor	0	0	6	13	19
---C. The integrator/comparator integrates information from multiple sources regarding the normal range of the regulated variable	0	2	5	15	16
---D. Physiological systems have a mechanism to establish the normal range for the regulated variable (a so-called set point)	0	1	7	11	19
---E. The integrator/comparator determines the difference between the signal from the sensors the normal range of the	0	1	8	14	15

regulated variable					
---F. The manipulator uses the this difference to change the activity of the effectors	0	2	10	10	16
---G. The control center may be distributed (different parts in different physical places)	0	2	14	17	5
V. Homeostatic processes require effectors	0	0	1	2	32
---A. Effectors can be cells or tissues, typically muscles (smooth muscle, cardiac muscle, skeletal muscle) or glands	0	0	4	3	31
---B. The manipulated variables are the result of the action of the effectors	0	2	3	13	20
---C. Altering the manipulated variables (e.g. HR) results in changes in the regulated variables (e.g., BP)	0	0	4	7	27
---D. The values of the manipulated variables can fall within a large physiological range	0	2	6	17	12