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Abstract:

Physiology faculty regard homeostasis as one of the core concepts their students should understand and be able to apply. We asked how 11 commonly-used, undergraduate physiology, anatomy & physiology (A&P), and biology textbooks introduce and use this core concept. We evaluated these textbooks to answer a number of questions: (1) do they contain an identifiable, introductory 'section' on homeostasis, (2) is this initial description (terms and figures) complete and accurate, (3) to what extent are the same terms and similar figures used in different textbooks, and (4) do subsequent chapters apply the ideas about homeostasis. Two preliminary findings are of interest. First, the language used to talk about homeostasis is inconsistent, even in the same textbook, often confusing and sometimes incorrect. Second, even when a suitable description of homeostasis is present, the same language and diagram(s) may not be used to reinforce student learning in describing homeostasis in organ system physiology. The consequences of these problems for student understanding and application of homeostasis are discussed. Supported by NSF grant DUE-1043443.

Introduction:

We assessed (1) what terms are used in the text and the glossary [Figure 1] and how these terms are used, (2) the types of figures used to summarize or model homeostasis [Figure 2] and (3) the consistent use of terms and figures to discuss homeostasis in four sections of the text [Figure 3]: (a) where homeostasis is introduced, (b) temperature regulation, (c) blood pressure regulation and the baroreceptor reflex, and (d) blood glucose regulation and the actions of insulin and glucagon.

Homeostasis Terms in Textbooks:

We examined the terms used in these textbooks and found some of them to be consistent, both across textbooks and within the chapters of individual texts.

Figure 1: Terms used in textbooks to describe homeostasis

Textbook term	200-level Human Anatomy & Physiology	200-level Human Physiology	200-level Introductory Biology	300-level Animal Physiology
Negative Feedback	✓	✓	✓	✓
Set Point	✓	✓	✓	✓
Normal Range	✓	✓	✓	✓
Control Center	✓	✓	✓	✓
Integrator (Integrating Center)	✓	✓	✓	✓
Sensor (receptor)	✓	✓	✓	✓
Effector	✓	✓	✓	✓
Target	✓	✓	✓	✓
Controlled Variable	✓	✓	✓	✓
Regulated Variable	✓	✓	✓	✓

Problems with Terms:

Missing terms. Some texts have no explicit reference to important elements of a homeostatic system.

- Sensors or sensory receptors are occasionally missing.
- Effectors or targets are occasionally missing.
- A consistent term for the variable that is held constant is often missing.

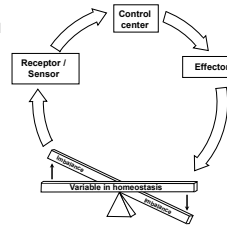
Different terms. All textbooks examined use the term "negative feedback" consistently. However, different textbooks use different terms for some critical elements in homeostatic systems. This can lead to problems transferring learning and confusion on assessment for some undergraduate students. In student interviews, we found 200-level physiology students may be confused if a novel term is used, if 'control center' for example, is used instead of 'integrator'.

- Integrator vs. Controller
- Effector vs. Target
- Set Point vs. Normal Range
- Controlled vs. Regulated Variables

Misused terms. Students (and textbooks) do not do a good job of differentiating between variables that can be changed by effectors or targets. Not all variables are homeostatically regulated and the terms 'regulated variable' & 'controlled variable' are often used inaccurately or inconsistently.

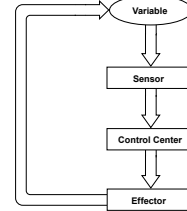
Iconic Types of Figures:

Figure 2a. The "See-Saw" (Δ): This type of figure makes the idea of "balance" explicit and the central feature of homeostasis.



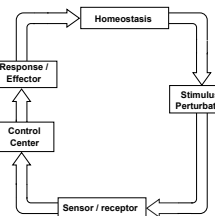
Critique: The emphasis on "balance" can result in or reinforce student misconceptions that these components are only active when there is an "imbalance." Set point is not represented in this type of figure. Negative feedback is not explicitly represented in this type of figure.

Figure 2b. The "Flow Diagram" (□): This type of figure makes the "steps" of the feedback loop or process explicit. Negative feedback is usually represented in this type of figure (by a (-) or a dashed line or a bar instead of an arrow).



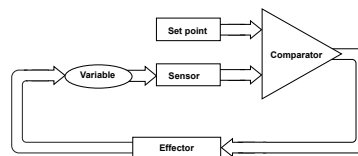
Critique: The flow diagram figures may reinforce student misconceptions that this process happens sequentially, with only one process (or box) operating at a time. Set point is often not represented in this type of figure.

Figure 2c. The "Circle" (○): This type of figure is usually used to explicitly link the stimulus and response via an integrator or control center.



Critique: This type of figure often omits a representation of the regulated variable. Thus, there is no depiction of an effector response altering a variable. "Homeostasis" is represented as a 'component' of the system (which it is not), which may result in serious misconceptions. Set point is not represented in this type of figure.

Figure 2d. The "Control Systems Diagram" (⇒): This type of figure represents the computational "boxes" that would be found in a quantitative model of the system and often makes mathematical operations explicit. Negative feedback is usually represented in this type of figure (by a (-) or a dashed line or a bar instead of an arrow).



Critique: This type of figure is uncommon in introductory physiology textbooks. It may be found in upper division textbooks. Students may not initially recognize the comparator element as the control center or integrator from their introductory courses. This particular representation does not explicitly visually represent the negative feedback that is present.

Consistent Use of Homeostasis Figures in Textbooks:

Some textbooks were consistent in their use of the same iconic figure within the chapters of an individual text, however, others were not. Undergraduate physiology students often struggle with recognizing, understanding and applying homeostasis in different physiological systems. Consistent use of an iconic figure, along with consistent use of terminology to refer to the components of a homeostatic system, provides students with potential reinforcement of learning.

Figure 3: Types homeostatic regulation figure in undergraduate textbooks

Key (types of figures)	Textbook section	Human Anatomy & Physiology	200-level Human Physiology	200-level Introductory Biology	300-level Animal Physiology
See Saw = Δ	Introduction to Homeostasis	○	○	○	○
Circle = ○	Temperature Regulation	-	-	△	△
Flow Diagram = □	Blood Glucose Regulation	No section	○	□	□
Control System = ⇒	Blood Pressure Regulation	□	○	○	○
Text Box = TB	Blood Pressure Regulation	□	○	△	□
Graph = G					
No summary figure = -	(# of authors)	(1)	(2)	(2)	(1)
		(1)	(1)	(6)	(6)
				(4)	(3)
					(3)

Figures & Student Misconceptions:

The iconic figures in textbooks can and should present a generalized model that can be applied to any specific homeostatic system. In doing so, instructors should be aware of some student misconceptions that may be reinforced by these simplified diagrams and important concepts that are not explicit in the figures should be addressed. This can be accomplished by eliciting student interpretation of these figures and by giving frequent feedback to build appropriate understanding.

Student Misconceptions

- **There is a single effector** (one 'box' means one effector or type of effector).
- **The sensors must be close to the control center** (because they are usually represented in series and closer to each other in the figures).
- **Effectors' responses directly change the regulated variable** (e.g., if an effector changes heart rate, then heart rate must be the regulated variable, not blood pressure).
- **Only one variable is controlled at a time** (because they only see one at a time).
- **Homeostatic processes only function during a perturbation or imbalance.**
- **Sensors only respond when the regulated variable is outside its normal range.**

Conclusions:

- Some terms are used consistently in the narrative of introductory physiology textbooks, especially 'negative feedback'. In some texts, however, there is very inconsistent use of terms used to describe homeostasis.
- There are pairs of terms that are used interchangeably in different textbooks (but used consistently within a textbook), including sensor/receptor, effector/target, integrator/control center.
- The process of negative feedback is not always shown explicitly in the figures used in a textbook.
- Some important concepts, e.g. set point, are not represented in the figures that are used to depict homeostatic regulation in a textbook.
- Figures are not always used consistently in different places within a textbook. This is a missed opportunity to reinforce student learning of this fundamental concept.

References:

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- McElhinny, T.L., Dougherty M.J., Bowling, B.V. and Libarkin, J.C. (2012) The Status of Genetics Curriculum in Higher Education in the United States: Goals and Assessment. *Science & Education* [published online December 2012]

