Abstract # 2368

A Conceptual Framework for the Core Concept of Mass Balance

Harold I. Modell[1] and Joel A. Michael[2]

[1]Physiology Educational Research Consortium, Seattle, WA, [2]Rush Medical College, Chicago, IL

Abstract

The core concepts of physiology are descriptions of phenomena that have great explanatory power in every area of physiology. They are "big ideas" that are comprised of many smaller ideas. The process of "unpacking" a core concept yields a hierarchically arranged statement of the sub-ideas that we have called a conceptual framework (CF). Our goal has been to produce CFs that will facilitate teaching and learning physiology.

We have unpacked three of the core concepts (homeostasis, flow down gradients, and cell-cell communication) and validated the resulting conceptual frameworks with feedback from the physiology teaching community; this work has been reported in Advances in Physiology Education.

Here we present our conceptual framework for the core concept of mass balance (conservation of mass). This core concept (and its CF) describes the consequences of moving mass (liquids, gases, solids) into and out of defined compartments. These ideas are applicable at every level of organization in the organism.

We will solicit feedback to validate the framework and its applicability to various levels of physiology instruction.

Background

Modell (2000) described a set of "general models" that he argued could be applied to explain and understand many different physiological phenomena. Subsequently, we modified and extended this general models list to obtain a set of 15 "core concepts" that physiologists agreed form the basis for understanding many physiological mechanisms (Michael & McFarland, 2011). Mass balance (aka conservation of mass; aka Modell's reservoir model) is one of these critical "core concepts."

A core concept is a general expression of a series of interrelated component ideas. To achieve maximum utility in applying core concepts two physiological phenomena, it is helpful to unpack the core concept into its component ideas. *The results of the unpacking yields a Conceptual Framework*. To date, we have developed and validated conceptual frameworks for the core concepts of homeostasis, flow down gradients, and cell-to-cell communication (Michael, et al. 2017).

We present our Conceptual Framework for the core concept of Cell Membrane in Abstract #2405 at this meeting. In this poster, we present our Conceptual Framework for the core concept a Mass Balance (Conservation of Mass).

In physiology, the concept of **Mass Balance** (Conservation of Mass) states that the quantity of mass in a given region of interest (compartment) must equal the quantity of that mass entering the compartment in a period of time plus the quantity of mass initially within the compartment minus the quantity of mass leaving the compartment during that period of time. The concept is applicable to all levels of biological systems from the organism to the cell.

Examples of Applying Mass Balance in Physiology

Cardiorespiratory:
- Alveolar Po_2 & Pco_2 (Alveolar Gas Equation)
- O_2 Uptake, CO_2 Output (Fick Equation)

Renal:
- Clearance

Muscle:
- Cytosolic [Ca^{++}]

Endocrine:
- Plasma Hormone Concentration

G-I:
- Gastric [H^+]

Neurophysiology:
- Neurotransmitter Concentration in Synaptic Cleft

Cell:
- Cell Membrane Receptor Number

Conceptual Framework for Mass Balance (Conservation of Mass)

MB1 Mass (or matter) can be liquid (e.g., water, blood), gas (e.g. Oxygen, Carbon Dioxide), solute within a liquid medium (e.g., ions, glucose, hormones), or solid (e.g., $Ca_3(PO_4)_2$ in bone).

MB1.1 The mass of liquid entering or leaving a compartment in a period of time refers to the flow rate of the liquid, regardless of solute content.

MB1.2 The mass of gas in the gas phase entering or leaving a compartment in a period of time is the total flow rate of gas times the fraction of the total that is the gas in question. (e.g., flow of air times the fraction of oxygen in air).

MB1.3 Solute in a liquid medium (e.g, plasma) may be dissolved (e.g., O_2, CO_2, free hormone, ions, glucose) or bound to a carrier (e.g., oxygen bound to hemoglobin, steroid hormone bound to a protein carrier).

MB1.3.1 Solute in a liquid medium (e.g, plasma) may be dissolved (e.g., O_2, CO_2, free hormone, ions, glucose) or bound to a carrier (e.g., oxygen bound to hemoglobin, steroid hormone bound to a protein carrier).

MB1.3.2 The quantity of mass entering or leaving a compartment in liquid medium over a period of time is calculated by multiplying the concentration of the mass (mass/volume) in the medium by the liquid flow rate (volume/time).

MB1.4 The rate of change of mass in solid form (e.g., bone) is determined by the rate of formation of the solid and rate of degradation of the solid.

MB2 The rate of change of mass in solid form (e.g., bone) is determined by the rate of formation of the solid and rate of degradation of the solid.

MB2.1 The compartment may have boundaries that exhibit recoil (i.e., elastic structures).

MB2.2 On a micro-level, the compartment may be a sub-region of a larger defined compartment (e.g, the glomerular capillary bed).

MB2.3 When determining entering and exiting flow rates of mass (e.g., solute), the size (volume) of a compartment can be viewed as fixed at any instant in time.

MB2.3.1 Because volume is assumed to be constant, a change in the quantity of solute within the compartment can be expressed in terms of concentration (e.g., osmolar concentration in the proximal tubule, glucose concentration in plasma, creatinine concentration in plasma).

MB3 Changes in the quantity of mass within a compartment depends on the initial quantity of mass in the compartment, the rate of entry of mass into the compartment, and the rate of exit of mass from the compartment.

MB3.1 "Entry" and "exit" of mass may occur by physical entry or exit of mass into/out of the compartment or by chemical transformation of one species into another within the compartment.

MB3.2 The rate of entry of mass into the compartment equals the sum of the entry rates from all entry paths.

MB3.3 The rate of exit of mass from the compartment equals the sum of the exit rates along all exit paths.

MB3.4 If the rate of entry equals the rate of exit, the compartment is said to be in a steady-state, and the quantity of mass within the compartment is constant.

MB3.5 If the rate of entry exceeds the rate of exit, the compartment is not in a steady-state, and the quantity of mass within the compartment increases.

MB3.6 If the rate of exit exceeds the rate of entry the compartment is not in a steady-state and the quantity of mass within the compartment decreases.

Next Step: Validation of Conceptual Framework

Validation Process (McFarland et al., 2016):

- Present proposed Conceptual Framework to physiology teachers at various academic levels.
- Using a Likert scale reflecting the importance of each element of the Conceptual Framework for student understanding of physiology, obtain feedback from physiology teachers.
- Include space on survey for additional comments from respondents.

We need YOUR HELP to evaluate our MB Conceptual Framework

- ***Please complete the survey from the envelope below.***
- ***Return the survey by placing it in the "completed" envelope below, OR return it using the stamped, self-addressed, envelope.***

Thank you.

References

- McFarland et al. (2016). A conceptual framework for homeostasis: development and validation. Adv. Physiol. Educ. 40:213-222.
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