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Developing a Concepts-based Physiology Curriculum for Bioengineering: A VaNTH Project

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***Abstract* – Physiology is recognized as a core topic for biomedical engineering but the physiology courses taught to bioengineering students vary widely in scope and depth from institution to institution. As part of the NSF-sponsored VaNTH Engineering Research Center in Bioengineering Educational Technologies curriculum project, a group of bioengineering, physiology, and learning science faculty have been developing a physiology taxonomy that could guide curriculum development. The initial efforts focused on a systems-based taxonomy but we have now changed to a concepts-based taxonomy that will be cross-referenced with topics taught in system physiology courses. The final product will include resources for developing a learner-centered bioengineering physiology curriculum.**

***Keywords*– physiology, curriculum, undergraduate education**

I. INTRODUCTION

Physiology is one of the core topics that bioengineers need to know and use, whether they are going to practice medicine, design medical devices or do biomedical research at any level of analysis. However, there is wide variability in the core content and the format of physiology courses currently taught in biomedical engineering (BME) training programs. One goal of the VaNTH (Vanderbilt-Northwestern-Texas-Harvard/MIT) Engineering Research Center in Bioengineering Educational Technologies is to create guidelines for an undergraduate BME physiology curriculum.

From discussions with BME faculty around the country and in looking at physiology course syllabi, we have discovered two basic patterns for training BME students in physiology. One approach is to put BME students into a biology department physiology course along with pre-medical students and biology majors. Although these BME students receive in-depth exposure to physiology, the content is less quantitative than they would receive in an engineering course and is usually algebra-based rather than calculus-based.

In the second approach, BME faculty teach the physiology course. Often these courses are not traditional survey courses that cover the different body systems with equal emphasis. Instead they emphasize areas related to BME faculty strengths and research interests and they may minimize or even ignore other body systems. The selective approach of these classes may not give students a broad understanding of physiology that they need when they enter the workplace.

Any guidelines devloped for a BME physiology curriculum must be flexible enough to accommodate both approaches. As part of the VaNTH consortium a team of bioengineers, learning scientists, and physiologists have been collaborating to define the core content and skills that should be included in all BME physiology courses. One of our first steps has focused on development of a physiology taxonomy.

II. SYSTEMS-BASED VS. CONCEPTS-BASED TAXONOMIES

Our initial attempts to develop a physiology taxonomy were organized around organ systems. This seemed to be a logical approach because most traditional physiology courses are taught this way. One advantage to this approach is that great deal of medical practice relies on understanding organ system function and interactions. In addition, the largest segment of bioengineers in industry works on instrumentation designed to replace or supplement the function of whole organ systems, such as pacemakers, dialyzers, and orthopedic implants.

There are several difficulties with the systems-based taxonomy, however. First, there is a tremendous amount of content that could be included, especially if the taxonomy includes microorganisms, plants, invertebrates, and nonmammalian vertebrates. Second, even if the taxonomy is restricted to vertebrates, coming to an agreement on what to include is difficult. Some years ago the American Physiological Society attempted to develop a content-based physiology taxonomy to guide curriculum development but abandoned the project because of lack of agreement about what should be included. Third, a systems-based taxonomy is not compatible with some of the physiology courses currently taught by BME departments. And finally, a systems-based taxonomy does not promote understanding of broad concepts. All too often physiology is taught as isolated organ systems and students fail to see the integration of function that occurs in intact organisms.

Subsequently we decided to create a concepts-based physiology taxonomy based on the content and skills that bioengineers need to be successful. The concepts-based taxonomy emphasizes basic principles and unifying themes that repeat across systems, such as pressure-flow relationships or the integrating concept of coordination and communication (see Table 1). However, because many physiology courses are organized around body systems, we plan to cross-reference the taxonomy to systems physiology topics. Ideally, this will create a tool to help faculty evaluate their individual physiology courses and ensure that they are covering the essential concepts.

As the basic concepts-based taxonomy develops, we are creating a detailed database that includes bioengineering teaching and homework examples, lists of existing curriculum materials that can be used in teaching the concepts, and notes to indicate where additional curriculum materials need to be developed. Once the curriculum is fully developed in firstdraft, we plan to disseminate it to bioengineers and physiologists for additional feedback. We hope that the final product will be a set of curriculum guidelines that can be used to assess and inform curriculum development in bioengineering physiology.

TABLE 1
UNIFYING CONCEPTS FOR PHYSIOLOGY

- Homeostasis and control systems
- Communication and coordination
- Structure/function relationships
- Levels of organization in the body
- Compartmentation
- Bioelectricity
- Biological energy
- Movement and associated forces (molecular to biomechanics)
- Biological transduction (molecular, sensory)
- Heat balance
- Mass balance
- Mass flow (transport)
- Emergent properties of complex systems
- Scaling in biological systems
- Physiological variables
- Biological units of measure

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