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COMMENTARY

Medical Biochemistry in the Era of Competencies: Is it Time for the Krebs Cycle to go?

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When reminiscing about medical school, practicing physicians frequently vent their frustration at having had to memorize clinically irrelevant information and often cite the Krebs cycle as an example. This common view, coupled with the future inclusion of basic biochemistry on the Medical College Admission Test (MCAT), prompts us to explore the role of biochemistry in medical school.[1] Is it time to remove the Krebs cycle from medical education? We think not. However, in this commentary, we call on fellow medical biochemistry educators to shift our legacy from memorized enzyme names to application of biochemical principles for clinical practice. While competency-based medical education has some limitations, it is a widely practiced model that can help educators make this transition.[2]

In response to unmet healthcare needs of patients and societies, competency-based medical education has attracted renewed interest in the past two decades.[2,3] The term "competencies" refers to the knowledge, attitudes, and skills required to practice medicine effectively. The Accreditation Council for Graduate Medical Education (ACGME) established six competency domains for U.S. residency training.[4] The Association of American Medical Colleges (AAMC) adapted these domains for medical schools in "Recommendations for Clinical Skills Curricula for Undergraduate Medical Education."[5] Similar frameworks have been adopted by other countries.[2,3] Recently, the AAMC and the Howard Hughes Medical Institute (HHMI) issued a joint report on the "Scientific Foundations for Future Physicians" that calls for more competency-based curricula, improved preparation in the basic sciences before medical school, and a greater role of science in the practice of medicine during medical school.[6] This report served as one of many inputs for the fifth comprehensive review of the MCAT exam.[1]

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Today's physician must be able to apply core science concepts to patients with complex clinical problems and to keep pace with the evolution of scientific understanding. Physicians must also be able to judge the validity of reports, advertisements and website content, and then communicate their insight to a diverse patient population. A deep understanding of biochemical principles underlies these skills. Through emphasis of both knowledge and skill, competency-based curricula help students achieve these goals. For many institutions, implementation of such a curriculum will require a dramatic shift in the way biochemistry is taught. Several basic science professional organizations have begun to move towards competency-based education by creating detailed learning objectives and in some cases mapping them to the ACGME competency domains.[7-9] However, until now, no published, nationally accepted objectives or competencies for medical biochemistry education existed.

We constructed a set of competencies within the ACGME competency domains to identify the knowledge, skills and attitudes medical students should develop in relation to biochemistry. The goal was to produce a set of measurable, behavior-based competencies that are applicable to all medical schools and prepare students to absorb future scientific developments. We adapted some ideas and language from the "Recommendations for

Clinical Skills Curricula for Undergraduate Medical Education", including the breakdown of the Patient Care competency domain into clinical testing, diagnosis, and clinical intervention.[5] The AAMC-HHMI report served as an early inspiration, particularly the notion that "curiosity, skepticism, objectivity, and the use of scientific reasoning are fundamental to the practice of medicine…[and] should permeate the entire medical education continuum."[6] Several members of the Association of Biochemistry Course Directors (ABCD), a national professional organization of medical biochemistry educators, improved a draft of the biochemistry competencies at a 2011 meeting; the results are shown in Table 1. All meeting attendees (~85) voted to accept the revised competencies.[10]

Full realization of the biochemistry competencies listed in Table 1 will require adherence to two principles. First, cooperation and communication among faculty in many fields is a must. No competency is limited solely to biochemistry; instead, each involves a biochemistry contribution to a multidisciplinary goal. Second, at least some biochemistry learning experiences must occur in an authentic context of patient care. Ideally, biochemistry learning opportunities are provided throughout the entire medical curriculum.

In order for faculty to determine whether students are progressing towards competency, specific milestones or measurable learning objectives that reflect longitudinal development must be identified. Table 1 provides a sample learning objective for each competency. At the 2011 meeting, ABCD members created the first comprehensive set of biochemistry learning objectives.[10] Draft lists of these objectives are available at http://abcd.wildapricot.org/ or on request of the authors.

Multiple choice tests alone, even with clinical and research scenario-based questions, will be insufficient to assess all competencies. A variety of assessment tools, employed frequently and formatively, will be needed to determine whether students are on the envisioned trajectory for achieving competency in all domains.[11,12] These might include Objective Structured Clinical Examination (OSCE)-type exams, reflections, portfolios, simulation, and qualitative feedback from faculty and peers.

So, what should our response be to those who suggest removing the Krebs cycle from medical education? If the proposed MCAT changes come to fruition, all U.S. medical students will enter school with a basic understanding of this central metabolic pathway. However, if students are to achieve the competencies proposed here and by the AAMC/HHMI report, biochemistry educators need to help them connect knowledge of the Krebs cycle to clinical medicine. Students will need to develop a working knowledge of the links between Krebs cycle flux and the rates of metabolism of sugars, fats and amino acids. Budding physicians should be able to describe the roles of B vitamins in metabolism (many of which function as cofactors for enzymes in the Krebs cycle). They also need insight into testing for Krebs cycle enzyme mutations in patients with neoplasms such as paraganglioma or cutaneous leiomyomas.[13] Finally, they should be able to explain these principles to their colleagues and their patients, and be ready to accommodate new scientific discoveries into their approach to patient care. If we drive learning with these applications, we will contribute more significantly to the development of competent physicians who, we hope, will remember their medical biochemistry education fondly. Instead of throwing out an old cycle, let us fit it with new wheels.

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Competency Domain	Proposed biochemistry competency	Sample learning objective
Medical Knowledge	Apply and integrate molecular and metabolic knowledge of conditions and disease states for clinical problem solving (e.g., diabetes, carcinogenesis, mental illness).	Explain the biochemical basis of (disease).
	Apply molecular and metabolic reasoning to evaluate clinical and translational research.	Describe how the development of effective therapies is based on an understanding of the molecular or metabolic nature of (disease).
Patient Care Sub-Domain: Clinical Testing	Select, justify, and interpret the results of clinical tests in order to identify likely molecular and metabolic causes of disease states (e.g., PCR, complete blood count, comprehensive metabolic panel).	Predict the results of (specific lab tests) for a patient with (specific disease/condition).
Patient Care Sub-Domain: Diagnosis	Based on patient history, physical exam, medical record, and/or laboratory test results, develop differential diagnoses for molecular and metabolic causes of disease states (e.g., metabolic acidosis, hyperbilirubinemia, hypoglycemia, hemolysis).	Prioritize and justify diagnoses that explain a (presenting symptom, physical exam finding, lab test).
Patient Care Sub-Domain: Clinical Intervention	Select and apply preventive, curative, and/or palliative strategies for the management of conditions or disease states with a molecular or metabolic basis (e.g., hypercholesterolemia, Lynch syndrome, hemoglobinopathies, glucose 6-phosphate dehydrogenase deficiency, PKU, poisoning).	Explain the biochemical basis of the use of (specific clinical intervention) in the treatment of (specific disease/condition).
	Predict the effectiveness of, and possible adverse effects associated with, interventions for conditions or diseases based on knowledge of molecular, genetic and cellular regulatory mechanisms (e.g., reduction of dietary trans fats for dyslipidemia, insulin analogs for hyperglycemia, allopurinol for hyperuricemia).	Explain the biochemical basis of (specific toxicities) seen with (specific clinical intervention).
Practice-Based Learning and Improvement	Evaluate the molecular and metabolic plausibility of claims made in the medical and lay public literature based on appraisal of scientific evidence and biochemical reasoning.	Produce a written or oral evaluation of an advertisement for a (drug, nutritional supplement, etc.), citing current literature.
	Demonstrate curiosity about the molecular and biochemical basis for the maintenance of health and the causation of disease.	Formulate a question, the answer to which could improve diagnosis and/or treatment of patients.
	Demonstrate knowledge and appropriate use of information literacy for the clinical diagnosis, testing, and understanding of biochemistry-based conditions.	Conduct a literature search and identify the most relevant articles or other forms of information regarding (disease).
	Based on assessment data and feedback related to biochemistry, reflect on one's own performance to identify strengths and challenges, set learning and improvement goals, and engage in appropriate learning activities to meet those goals.	Document evidence of reflection on progress toward learning goals.
Interpersonal and Communication Skills	Effectively explain to patients from a variety of backgrounds the molecular and metabolic basis of conditions and disease states and how lifestyle and/or therapeutic interventions can alter their manifestations.	Explain the molecular basis of (disease) to a standardized patient.
	Communicate biochemical reasoning effectively with peers, medical school staff and faculty, and other members of the health care team.	Teach a peer about (biochemical process) and ensure that the peer meets the relevant learning objectives.
	Communicate enthusiasm for knowledge to patients and professional colleagues.	Ask thoughtful questions regarding how we know what we know, and how we can learn more.

Table 1. *Proposed biochemistry competencies and sample learning objectives*

Professionalism	Demonstrate empathy and respect towards patients regardless of the biochemical nature of their disease and with sensitivity to diversity (e.g., obesity, depression, alcoholism).	Reflect about your personal biases regarding the causes of (disease).
	Demonstrate respect, accountability, and reliability in interactions with patients, families, peers, and other healthcare professionals.	Arrive on time to required sessions and meet deadlines without reminders.
	Demonstrate ethical behavior and integrity in one's work.	Cite resources appropriately.
Systems-Based Practice	Demonstrate effective use of nutrition, lifestyle and genetic counseling referral services.	Identify when to consult a dietitian or genetics counselor.
	Contain healthcare costs by selecting and justifying diagnostic measures and treatments.	Prioritize and justify the use of (specific diagnostic test) for patients with (specific signs and symptoms).

Table 1 (cont.). *Proposed biochemistry competencies and sample learning objectives*

References

1. American Association of Medical Colleges [homepage on the Internet]. Washington, DC: AAMC; c1995-2011 [cited 2011 Aug 22]. MR5 committee; [about 2 screens]. Available from: https://www.aamc.org/initiatives/mr5/preliminary_recommendations/182498/preliminary_recommendations.html.
2. Frank JR, Snell LS, Cate OT, Holmboe ES, Carraccio C, Swing SR, Harris P, Glasgow NJ, Campbell C, Dath D, Harden RM, Iobst W, Long DM, Mungroo R, Richardson DL, Sherbino J, Silver I, Taber S, Talbot M, Harris KA. Competency-based medical education: theory to practice. *Med Teach*. 2010;32(8):638-45.
3. Albanese MA, Mejicano G, Mullan P, Kokotailo P, Gruppen L. Defining characteristics of educational competencies. *Med Ed*. 2008;42(3):248-255.
4. Accreditation Council for Graduate Education [homepage on the Internet]. Chicago, IL: ACGME; c2000-2011 [cited 2011 Aug 22]. Outcome Project [about 2 screens] http://www.acgme.org/outcome/comp/refList.asp.
5. American Association of Medical Colleges [homepage on the Internet]. Washington, DC: AAMC; c1995-2011 [cited 2011 Aug 22]. AAMC Project on the Clinical Skills of Medical Students; [about 2 screens]. Available from: https://www.aamc.org/download/130608/data/clinicalskills_oct09.qxd.pdf.pdf.
6. Howard Hughes Medical Institute [homepage on the internet]. Chevy Chase, MD: HHMI; c2011 [cited 2011 Aug 22] HHMI and AAMC, Scientific Foundations for Future Physicians; [about 3 screens] Available from: http://www.hhmi.org/grants/sffp.html
7. The American Physiological Society [homepage on the Internet]. Bethesda, MD: APS; c2008 [cited 2011 Sept 6]. Medical Physiology Curriculum Objectives Project; [about 10 screens]. Available from: http://www.the-aps.org/education/medphysobj/medcor.htm
8. Booth SJ, Burges G, Justement L, Knoop F. Design and implementation of core knowledge objectives for medical microbiology and immunology. *JIAMSE*. 2009;19(3):100-138.
9. Association of Professors of Human and Medical Genetics [homepage on the Internet]. Bethesda, MD: APHMG; c1995 [cited 2011 Sept 6]. APHMG Medical School Core Competencies in Genetics 2010; [about 2 screens]. Available from: http://www.aphmg.org/pdf/Med%20Competencies.pdf.
10. Ronner P, Sabina R, McKee E, Fulton TB, Ferrier D, Noramly S. Meeting report: Teaching biochemistry to students of medicine, dentistry & pharmacy; 3rd conference of the Association of Biochemistry Course Directors (ABCD), Myrtle Beach SC, USA, April 30-May 4, 2011. *Med Sci Educ*. 2011 Jul;21(3);245-249.
11. Holmboe ES, Sherbino J, Long DM, Swing SR, Frank JR. The role of assessment in competency-based medical education. *Med Teach*. 2010;32(8):676-682.
12. Norcini JJ, Holmboe ES, Hawkins RE. 2008. Evaluation challenges in the era of outcomes-based education. In: Holmboe ES, Hawkins RE, editors. Practical Guide to the Evaluation of Clinical Competence. Philadelphia, PA: Mosby/Elsevier. pp 1–9.
13. Frezza C, Pollard PJ, Gottlieb E. Inborn and acquired metabolic defects in cancer. *J Mol Med*. 2011 Mar;89(3):213–220.