HHMI-NEXUS: Competency-Based Undergraduate Science Preparation of Health Professionals and Biological Scientists

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A national effort is under way to develop, assess, and disseminate nationally a competency-based program for the first two college years of mathematics, physics, and chemistry preparation of life scientists (including health professionals).

It is nonprescriptive; the purpose is to lower the barriers for colleges and universities to develop and adopt such a program.
Goals for this Talk

• To show why and how such an effort developed
• To show how the effort is “organized”
• To show why Veterinary Medicine Educators might/should be interested
• To illustrate some of the difficulties and possible solutions
• To show the Purdue (chemistry) part of the project as a microcosm of the project as a whole
How This All Began
(a.k.a. Forces of Change)

1. Faculty hallway conversations

Why is organic chemistry taught the same way as it was 50 years ago?
2. An emerging national debate
Response to the new MCAT
*ASBMB premedical curriculum recommendations*

BY CHARLES BRENNER AND DAGMAR RINGE

EDITOR’S NOTE: At the December Council meeting of the American Society for Biochemistry and Molecular Biology, the American Society for Biochemistry and Molecular Biology (ASBMB) discussed the implications of the new MCAT. The Council recommended that universities provide resources to courses on subjects that will be tested in the revised MCAT. Moreover, disciplines already represented in the MCAT may need to shift resources to other areas.
“Instead of the current chemistry sequence, colleges could expose premedical students to general chemistry, organic chemistry, and biochemistry in a 2-year sequence that provides the foundation for the study of biologically relevant chemistry.”
3. Reports by leading national organizations

- 2003
  - "SFFP"
- 2009
  - "SFFP"
- 2010
  - "BIO"
  - "VISION AND CHANGE"
Examples of HHMI/AAMC Competencies (from the SFFP document)

**Competency E1:** Apply quantitative reasoning and the language of mathematics to describe or explain phenomena in the natural world.

**Competency E2:** Demonstrate understanding of the process of scientific inquiry, and explain how scientific knowledge is discovered and validated.

**Competency E3:** Demonstrate knowledge of basic physical principles and their applications to the understanding of living systems.

**Competency E4:** Demonstrate knowledge of basic principles of chemistry and some of their applications to the understanding of living systems.

1. *Demonstrate knowledge of atomic structure.*
2. *Demonstrate knowledge of molecular structure.*
3. *Demonstrate knowledge of (inter)molecular interactions.*
4. The HHMI–NEXUS Experiment Grant

HHMI Experiment Grant Program RFA and submission

Collaborative HHMI Experiment Grant submission

Funding by HHMI as the NEXUS program
The NEXUS goal is to develop a series of modules and assessments that can be used in a competency-driven curriculum.
Local, NEXUS, National

NEXUS PARTNERS

Faculty in each discipline willing to tweak, try, adopt, and assess resources

Liaison with national societies in primary areas

LOCAL

Resource module development in a specific discipline; local assessment

NATIONAL

NEXUS provides and posts resources and assessments; members write papers and give talks

Image courtesy of Florida Center for Instructional Technology
5. The MCAT Revisions

- The AAMC has mandated an MCAT revision to take effect in 2015 (MR5)
- Nominally, this will test students on the competencies in SFFP
- The promise of this revision has spurred chemistry departments into thinking seriously about modifying pre-professional chemistry courses
1185 respondents including 4th year medical students, residents, and faculty were surveyed on the importance of subjects to the present curriculum.

622 faculty respondents were surveyed on importance to the future curriculum.

Did not ask about mathematics other than statistics; did not ask about the importance of subjects as foundations for premedical training.
MR5 Subject Survey Report (Spring 2010)
(Importance of various subjects to future medical curriculum)

- Biochemistry: 3.34
- Biology: 3.12
- Cellular/Molecular Biology: 3.07
- General Chemistry: 2.96
- Physics: 2.91
- Research Methods & Statistics: 2.86
- Organic Chemistry: 2.65
- Behavioral Sciences: 2.39
• Some *unimportant* subjects
  – Organometallics (e.g., Grignard reagents) 1.67
  – Alkyl halides 2.15
  – Nonmetals 1.65

• Some *important* subjects
  – Acids and bases 4.19
  – Intermolecular forces 3.47
  – Phosphorus chemistry (e.g., phosphate esters) 3.59
  – Amino acids and proteins 4.27
6. American Chemical Society (ACS) Committee on Education (SOCED)

- The ACS appointed a subcommittee of SOCED to work on the “organic chemistry problem”: *In what ways might chemistry departments respond to SFFP to revise organic chemistry curricula so as to meet the challenges of SFFP?*
- Efforts are designed to be helpful, not prescriptive.
Undergraduate population
Premed students
Small schools, unified tracks
Specific courses and grades
Local
Proprietary, global

All preprofessional and biological science
Large schools, separate tracks
Interdisciplinary courses; competencies
Global; role of MCATs
National
Open source, modular

Curriculum development
Admission criteria for professional schools
Curriculum assessment
Impact
Learning resources

Question/Tensions
The Process of Curricular Change

• We are focusing on chemistry; similar efforts are going on in mathematics and physics.
• We are seeking a major change in how chemistry is taught to biological sciences students at many institutions, including our own.
• Chemistry will be taught differently to majors and biological science students.
• (A few institutions have made this change.)
• Categories of resistance
  – Philosophical
  – Resource issues
Biological science students (and pre-professional students) should have completed gen chem, sophomore physics, organic chem, basic calculus, and one semester of biochemistry in 2 years.

- Prepares students for advanced study in biology and undergraduate research
- Allow more room in curriculum for additional science electives or humanities electives.
- Prepares pre-professional students for earlier admission into professional schools.
- Would appear to be helpful in shortening time to degree of DVM students.
The Process of Curricular Change: Organizational Goals

2. Integration will be provided by crosstalk between courses and instructors.
   • Idealistically, integration could be achieved by throwing out existing courses and starting over.
   • Practically, this approach virtually guarantees administrative and faculty pushback.

Course reform is easier if it can be carried out within existing courses and administrative structures. Evolution is more practical than revolution.
Formerly: 2 semesters of General Chemistry, 2 semesters of organic chemistry, Biochemistry later, perhaps as late as 4th year
The Process of Curricular Change: Curricular Goals

3. Courses should be developed from biologically relevant topics and examples.
   - "Biologically relevant" does NOT mean "less rigorous." Gone are the days when a student chooses biology because they want to avoid chemical and mathematical rigor.
   - Organic chemistry will be based on chemistry and mechanisms relevant to biological models rather than total synthesis.
Examples from General Chemistry

- Chemical equilibrium: applied to biological reactions
- Electrochemistry: applied to electron transport and membrane potentials rather than batteries
- Kinetics: incorporates enzyme kinetics
Examples from Organic Chemistry

• Stress chemistry relevant to biology. Show how each topic selected meets one or more SFFP competencies.
• Omit total synthesis and many synthetically important reactions that have little relevance to biology.
• Stress acid–base chemistry.
• Include a full exploration of stereochemistry.
• Develop an understanding of molecular properties and noncovalent molecular interactions relevant to biology (e.g., noncovalent forces, solubility).
Include oxidation and reduction in organic chemistry and relate to biological oxidation and reduction, including Phase-I metabolism, rather than “43 ways to oxidize an alcohol.”

The basic principles of biocatalysis
- Forces involved in binding events
- Approximation and intramolecularity
- Metal ions as activators
- The role of water (or its absence)
- Stereochemical specificity

How to dissect many, if not most, steps of biochemical pathways in terms of their chemical logic.
The Organic Chemistry Course Is NOT—

• —a Biochemistry course
  – The course will focus on chemical aspects of selected processes as examples of how nature brings about (bio)chemical transformations.
• —designed to give the students an overall view of bioenergetics and “big-picture” biochemistry.
  – the goal of the course is to stress principles of chemical reactivity relevant to biology

... but it should provide a better foundation for biochemistry and medicine
4. Laboratories should be re-designed with “guided-design” and/or “research” approaches rather than “cookbook” approaches.

5. Resources (e.g., TAs) might be redistributed, but don’t take them away. Corollary: “Incentivize” reform with resources.

If faculty resources are not threatened, faculty are more likely to concentrate on curricular issues than defending turf.
6. Provide resources ("modules") based on SFFP competencies to fill in the inevitable gaps in conventional textbooks.
   • Example: Acids and bases in a biological context (used in both gen chem and organic)
   • Example: Enzyme kinetics in the gen chem kinetics instruction. (Can then be used by organic and biochemistry.)
   • Example: Intermolecular noncovalent interaction
   • Example: Intramolecularity and catalysis.
The Process of Curricular Change: Goals

7. Plan meaningful assessments.
   • The modules will be accompanied by validated and tested assessment questions.
   • The general chemistry course will be compared with the two-semester sequence. (More specifics later)
   • The modules will be tested by NEXUS member institutions.
   • National-level assessments(?)


General Chemistry (GC) Assessment Plan
(via Purdue Assessment Minigrant)

• Compare performance in organic chemistry of one-semester GC students with that of two-semester GC students in prior years.
  – Result: No significant difference

• Assess the performance of one-semester GC students on appropriate questions of the ACS General Chemistry Exam.
  – Result: Excellent performance, but comparison with ACS norms has not been done yet.
National-Level Assessment

• University of Miami PRISM program
  1. Full intervention group; PRISM students (Program in Integrated Science and Math)
  2. Non-intervention group; premedical students not in PRISM
  3. Case studies that utilize all basic sciences

• MCATs
  – MCATs being revised now; new MCAT to be administered in 2015
  – AAMC “MR5” committee has dialog with NEXUS; basic sciences part of exam will hopefully be based on SFFP competencies
National-Level Assessment, contd.

• Other “CATs”
  – PCAT, VCAT: Would they be good ways to assess student scientific preparation? They might provide a common assessment for students from diverse programs.
  – If “CATs” are used, there can’t be a disconnect between avowed objectives and the questions themselves.
• An ACS Chemical Biology Exam(?)
Three Elephants in the Room

- **Resources**
  - How do departments serve chemistry majors and a large number of pre-professional students with current resources?
  - If a department changes the number of semesters of Gen Chem, what happens to its TA resources?

- **MCATS and Other Assessments**
  - Will the MCATs reflect the HHMI–AAMC (SFFP) competencies, or will there be a disconnect?

- **Professional-School Requirements**
  - Will Professional Schools adopt some flexibility in course requirements?
Resource Issues: Purdue Example

- Two semesters of Gen Chem replaced by one semester—potentially affects ca. 800 students and many TA positions. Possible solutions:
  - Test the idea on a limited cohort of students (about 250) to show whether it works (started 1+ yr ago)
    - College of Pharmacy volunteered because it fit well into plans for a new Pharmacy curriculum, and it allowed students to continue to complete their pre-pharmacy preparation in 2 years.
  - Do not reduce TA positions overall
  - Move TAs from Gen Chem to Biochemistry within the Chemistry Department
  - Find interesting and creative ways to use TAs, e.g.
    - Developing modules, new lab experiments, online homework, assessments
Chemistry @ Purdue

• The “New” General Chemistry started two years ago for test students.
• “New” organic course curriculum now being taught to test students.
• Module development (modules based on HHMI competencies) and assessment is just beginning.
  – Modules to be developed and tweaked with inputs from other institutions
  – Modules used locally and assessed with validated assessments
  – Modules exported to NEXUS partners for testing
Organic Chemistry: National Issues

- Purdue 1–2–1 model will not be practical for all schools
- Tension: How to provide a viable ACS-certified chemistry major for a relatively small group of students vs. provide a course that responds to the SFFP for a larger group of nonmajors
  - One semester organic intro followed by one-semester specialty courses(?)
  - The ACS is trying to develop sample curricula to help people to meet this challenge in different ways.
  - The NEXUS modules will also provide resources
Reaction from Veterinary Education

• What is your reaction to these ideas?
• Are we missing some key components that you think are important?
• Questions?