Science education for premedical and medical students:

Report from the SFFP committee

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Need for Change

- The approach to science education in the premedical and medical curriculum is **largely unchanged** for decades ….

  …. while biomedical sciences have changed dramatically.

- Readiness for medical school admission is defined by:
  - lists of required courses
  - content of the MCAT examination

- Both are rather static criteria, not influenced by research or by changes in the nature of medical science

Need for Change

- The *Bio2010* report (NAS, published 2002) concluded:
  - Fixed premedical science course requirements and MCAT content constrain the undergraduate science curriculum
  - This applies not just in biology but across the sciences

An example:

- Many students who would make excellent physicians identify premedical science course requirements such as Organic Chemistry as the reason they chose another career.
- Institutions wishing to innovate their chemistry curricula find it difficult to do so, given the externally imposed pre-med requirements

The SFFP Project

- Initiated and organized by
  - Association of American Medical Colleges (AAMC)
  - Howard Hughes Medical Institute (HHMI)
- Committee:
  - medical school faculty
  - undergraduate science educators.
- Diverse institutions
- MCAT leadership (a division of AAMC) closely involved

Acknowledgments:
Project sponsorship, leaders and senior staff

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  - Peter Bruns, VP for grants and special programs
  - William Galey, Program Director, Graduate and Medical Science Education

- **Association of American Medical Colleges**
  - David Korn, Chief Scientific Officer (until 10-2008)
  - Karen Mitchell, Sr. Director, Admissions Testing Services
  - Jodi B. Lubetsky, Manager, Science Policy

Committee members are drawn from both medical school and undergraduate institutions

Robert Alpern, Co-chair		*Yale School of Medicine*
Sharon Long, Co-chair		*Stanford University*
Science faculty [grad/undergrad]		
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Karin Akerfeldt	Chemistry	*Haverford College*
Julio de Paula	Chemistry	*Lewis and Clark College*
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Dierdre Labat	Biology	*Xavier University*
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Dee Silverthorne	Biology	*University of Texas*

Committee members are drawn from both medical school and undergraduate institutions

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Andrew Fishleder	*Cleveland Clinic*
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Gary Gibbons	*Morehouse School of Medicine*
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Lynne Kirk	*U.T. Southwestern Medical Center*
Bruce Korf	*University of Alabama Medical School*
Vinay Kumar	*University of Chicago Medical School*
Paul Marantz	*Albert Einstein School of Medicine*

Charge to the Committee

- What science competencies should medical students demonstrate, before receiving the M.D. degree?

- What scientific competencies should premedical students demonstrate *before* entry into medical school.

- Emphasis should be on defined areas of knowledge, scientific concepts, and skills *rather* than on specific courses.

Strategy - 1

- Undergraduate course requirements should be eliminated and replaced with a list of required competencies.
  - undergraduate schools will have flexibility to design new curricula
  - interdisciplinary classes may be offered
  - innovative educational programs may encourage students to enter medicine and the related biomedical sciences.

Strategy - 2

- No net increase in premed science requirements
  - Liberal arts are important for education of physicians
  - Presently, 1 year each of: physics, biology, general chemistry, organic chemistry and calculus
  - If we recommend new competencies, then un-needed material should be removed from overall curriculum

Strategy - 3

- Scientific competencies should be those required to practice medicine
  - includes interpretation of the scientific literature
  - critical and skeptical thinking, analysis
- These competencies are not designed to prepare for a career in biomedical research.
  - Some schools may design curricula to prepare students for careers in research
  - Choice is up to each individual institution

Strategy - 4

- Scientific competencies:
  - Reflect recent advances in the biomedical sciences
  - emphasize the increasingly close relationship with the physical and mathematical sciences.
- Examples:
  - Statistics is important to allow physicians to be a critical consumer of data from new clinical trials, research on genomic associations, etc.
  - Biochemistry is more relevant than some aspects of organic chemistry presently emphasized

Strategy 5

- Require more relevant competencies for the entering medical students:
  - Entering students will be more evenly prepared for the first year medical curriculum, allowing medical educators to spend less time teaching the basics.
  - Medical schools may then be able to teach scientific material in a more thoughtful, less rushed manner, to cover additional material, and to emphasize research

Structure of Recommendations

Overarching Principles

- ***Competency (Medical or Entering) E1, E2, ….8***
  = broad statement of goal for understanding
  - Learning Objective 1, 2, etc
    competencies in various areas

      Examples 1, 2, etc.

Structure of Recommendations

Overarching Principles.

1. Demonstrate knowledge of, and ability to use basic principles of:
   - *Mathematics and Statistics*
   - *Physics*
   - *Chemistry*
   - *Biochemistry*
   - *Biology*

   needed for the application of the sciences to human health and disease

2. Demonstrate observational and analytical skills and the ability to apply those skills and principles to biological situations.

Entering Med Student Competencies: E1 – E8

1. *Apply **quantitative** reasoning and appropriate **mathematics** to describe or explain phenomena in the natural world*
2. *Demonstrate understanding of **the process of scientific inquiry**, and explain how scientific information is discovered and validated.*
3. *Demonstrate knowledge of basic **physical principles** and their applications to the understanding of living systems.*
4. *Demonstrate knowledge of basic **principles of chemistry** and some of their applications to the understanding of living systems.*
5. *Demonstrate knowledge of how **bio-molecules** contribute to the structure and function of cells.*
6. *Apply understanding of principles of how **molecular and cell assemblies, organs, and organisms** develop **structure** and carry out **function.***
7. *Explain how **organisms sense and control** their internal environment and how they respond to external change.*
8. *Demonstrate an understanding of how the **organizing principle of evolution** by natural selection explains the diversity of life on earth.*

Entering Med Student Competencies

- ***Competency E1.*** *Apply quantitative reasoning and appropriate mathematics to describe or explain phenomena in the natural world.*
- **Learning Objectives:**

1. Demonstrate quantitative numeracy and facility with the language of mathematics.
2. Interpret data sets and communicate the interpretations of those data sets Error analysis and statistical inferences from data sets
3. Make statistical inferences from data sets.
4. Extract relevant information from large data sets.
5. Make inferences about natural phenomena using mathematical models.
6. Apply algorithmic approaches and principles of logic (including the distinction between cause/effect and association) to problem solving.
7. Quantify and interpret changes in dynamical systems.

Entering Med Student Competencies

- ***Competency E1.** Apply quantitative reasoning and appropriate mathematics to describe or explain phenomena in the natural world.*
- **Learning Objectives:**

  5. Make inferences about natural phenomena using mathematical models.

  – Examples

- Describe the basic characteristics of models (e.g., multiplicative vs. additive).
- Predict short- and long-term growth of populations (e.g., bacteria in culture).
- Distinguish the role of indeterminacy in natural phenomena and the impact of stochastic factors (e.g., radioactive decay) from the role of deterministic processes.

Entering Med Student Competencies

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

Learning Objectives:

1. Demonstrate understanding of mechanics as applied to human and diagnostic systems.
2. Demonstrate knowledge of the principles of electricity and magnetism (e.g., charge, current flow, resistance, capacitance, potential, and magnetic fields).
3. Demonstrate knowledge of wave generation and propagation to the production and transmission of light and sound.
4. Demonstrate knowledge of the principles of thermodynamics and fluid motion.
5. Demonstrate knowledge of principles of quantum mechanics such as atomic and molecular energy levels, spin, and ionizing radiation
6. Demonstrate knowledge of principles of systems behavior, including input–output relationships and positive and negative feedback.

Entering Med Student Competencies

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

  3. Demonstrate knowledge of wave generation &propagation to the production and transmission of light, sound.

  - Examples

- Apply geometric optics to understand image formation in the eye.
- Apply wave optics to understand the limits of image resolution in the eye.
- Apply knowledge of sound waves to describe the use and limitations of ultrasound imaging.

Curricular Implementation

- Some schools may choose to stay with existing courses and assign those that address the required competencies to the premedical curriculum.
- Curricular innovation is encouraged.
  - Interdepartmental, interdisciplinary
  - The relevance of mathematics, physics and chemistry to biology and the biomedical sciences should be emphasized.

Future Plans

- Draft completed in February 2009
- Draft sent out for feedback from undergraduate and medical school leaders
- Report to be released in early summer
- Accompanying editorial in *Science*
- Now: coordinate work with undergraduate institutions, scientific disciplines, medical school and MCAT organizations
- How do we get from here to there?

Future Plans

How do we get from here to there?

National level: content of MCAT

- AAMC has scheduled review of MCAT
- Scientific and other content to be examined
- Two members of SFFP (including Robert Hilborn) are on the MCAT review committee
- Goal: test for competency, but not details reflecting the traditional paths to gain the competency

Future Plans

How do we get from here to there?
Undergraduate institutions

Implementation should be decided by each individual college/university

A role for:

- University leadership
- Departments
- Individual faculty
- Scientific disciplines

Science education for premedical and medical students:

Report from the SFFP committee

Science competency for *graduating physicians* (end of medical school)

- Considered diversity of medical school curricula, various approaches to basic sciences
- Checked our lists *vs* USMLE part 1 content
- Consulted previous MSOP documents
- Open discussions about changing and evolving needs in medical practice

Working draft of recommendations

8 major areas of competency for graduating physicians

Competency 1

- *Apply knowledge of molecular, biochemical, cellular, and systems-level mechanisms that maintain homeostasis, and the dysregulation of those mechanisms, to the prevention, diagnosis and management of disease*

Competency 2

- *Use the principles of genetic transmission, molecular biology of the human genome, and population genetics to infer and calculate risk of disease, to institute an action plan to mitigate this risk, to obtain and interpret family history and ancestry data, to order genetic tests, to guide therapeutic decision making, and to assess patient risk.*

Working draft of recommendations
8 major areas of competency for graduating physicians

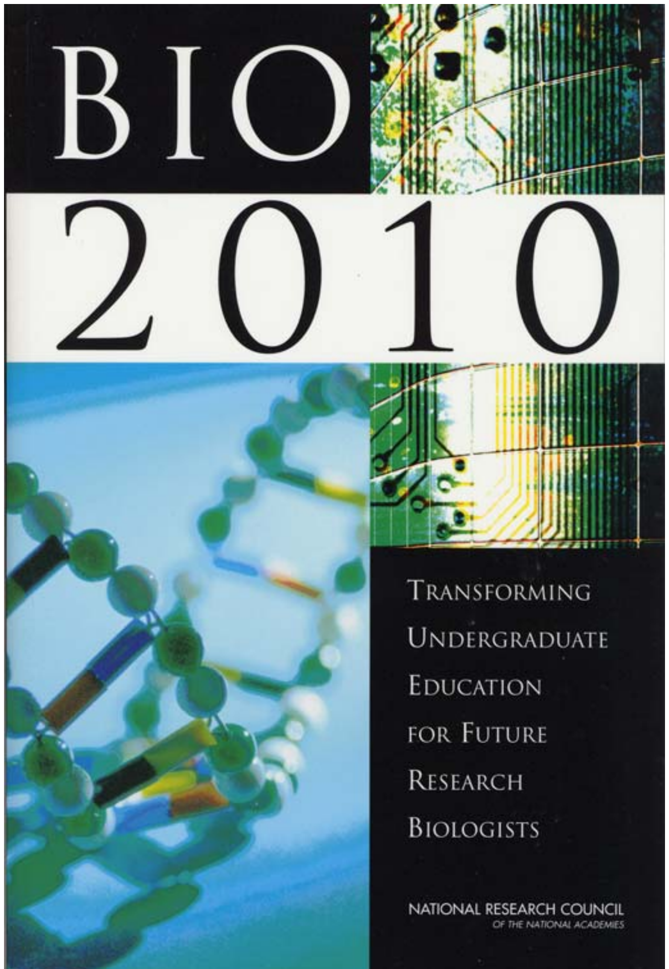
Competency 5

- *Apply the principles of the cellular and molecular basis of immune and non immune host defense mechanisms in health and disease to determine the etiology of disease, identify preventive measures, and predict response to therapies.*

Competency 8

- *Apply quantitative knowledge and reasoning - including integration of data, modeling, computation, and analysis – and informatics tools to diagnostic and therapeutic clinical decision-making.*

Overview: the Bio 2010 report



- Study carried out by the National Research Council of the NAS
- Sponsored by NIH and HHMI
- Requested to examine undergraduate education required to prepare the next generation of life science researchers
- Implementation has started at many colleges and universities
- Chaired by Lubert Stryer; participants -
  - Committee for overall report
  - Panels for
    - chemistry
    - mathematics + computer science
    - physics + engineering
  - Workshop on innovative undergraduate education

Examples of curriculum change

- Integrate physics and chemistry content from prerequisite classes into biology classes
- Expand expectations for math and computing
  - Calculus
  - Linear algebra
  - Probability and statistics
  - Dynamical systems
  - Information and computation
  - Data systems
- Evolve content of chemistry -- *examples*
  - Earlier inclusion of heterocyclic chemistry, carbohydrates
  - Talk about chemistry of unsolved biological problems
- Evolve content of physics -- *examples*
  - Use physics as venue to introduce dynamical systems, emergent systems, pattern formation