The Next Generation Science Standards, AP Physics 1 and 2, and the Revised MCAT: The New Face of STEM Education

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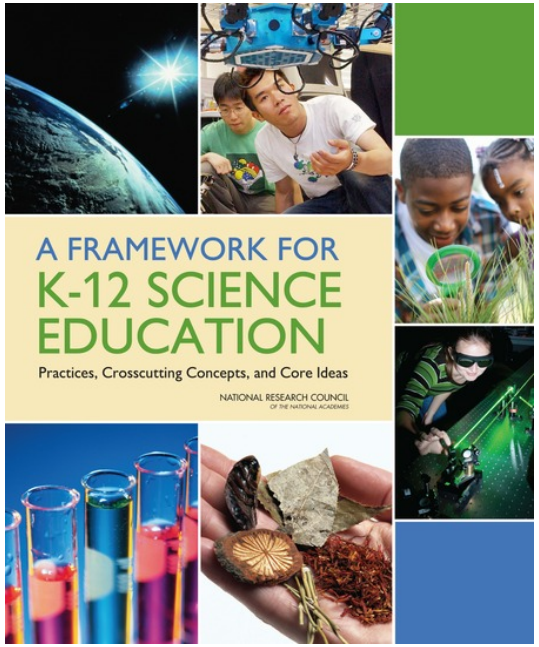
Outline

- The Next Generation Science Standards
- AP Physics 1 and 2
- The review and redesign of the Medical College Admissions Test (MCAT)
- What is in common? Implications for introductory physics education

Next Generation Science Standards

- *A Framework for K-12 Science Education: Practices, Cross-cutting Concepts, and Core Ideas*, National Research Council report (2012)
- *Next Generation Science Standards* (2013)



Next Generation Science Standards

- Input from 26 "lead partner" states (including GA, NC, and TN), professional societies (including NSTA, AAPT…), organized by Achieve, Inc. and financed by Carnegie Corporation of New York
- NGSS = Student Performance Expectations written as a combination of disciplinary core ideas and science and engineering practices
- www.nextgenscience.org
- 9 states have formally adopted NGSS

Disciplinary Core Ideas

- Earth and Space Science 1

  Earth and the moon, sun, and planets have predictable patterns of movement. These patterns, which are explainable by gravitational forces and conservation laws, in turn explain many large-scale phenomena observed on Earth.

PS4.B

- By understanding wave properties and the interactions of electromagnetic radiation with matter, scientists and engineers can design systems for transferring information across long distances, storing information, and investigating nature on many scales—some of them far beyond direct human perception.

PS4.B
Grade 2

- ***By the end of grade 2.*** Objects can be seen only when light is available to illuminate them. Very hot objects give off light (e.g., a fire, the sun).

NGSS DCI Example

- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

NGSS Student Performance Expectations = DCI + Sci-Eng Practice

- HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

Student Performance Expectation DCI + Sci-Eng Practice

- HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. [*Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*]

NGSS Summary

- NGSSs are **student performance expectations**, not a curriculum
- If a student meets NGSS, is the student ready for college or for a STEM career?
- Many "standard" high school physics topics are not in *A Framework* or *NGSS*: electrical circuits, fluids, ….
- How will engineering practices be included?

AP Physics 1 and 2 (the new AP Physics B)

- First administration May 2015, courses start in Fall 2014.
- **Two** year-long courses replace AP Physics B
- AP Physics 1 - Newtonian mechanics (including rotational dynamics and angular momentum); work, energy, and power; mechanical waves and sound; introduction to electric circuits.
- AP Physics 2 - fluid mechanics; thermodynamics; electricity and magnetism; optics; atomic and nuclear physics.

AP Science Practices

1. The student can use representations and models to communicate scientific phenomena and solve scientific problems.
2. The student can use mathematics appropriately.
3. The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.
4. The student can plan and implement data collection strategies in relation to a particular scientific question. (Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction and/or archived data.)

AP Science Practices

5. The student can perform data analysis and evaluation of evidence.
6. The student can work with scientific explanations and theories.
7. The student is able to connect and relate knowledge across various scales, concepts and representations in and across domains.

AAMC

Medical College Admission Test

- MCAT
  - Taken by over 50,000 students annually
  - Required by most US and Canadian medical schools
- Just one of many pieces of information used by medical school admissions committees
  - Transcripts
  - Personal statements and interviews
  - Letters of recommendation

The Scientific Foundations For Future Physicians Project (2009)

- Initiated and organized by
  - Association of American Medical Colleges (AAMC)
  - Howard Hughes Medical Institute (HHMI)
- Committee:
  - medical school faculty
  - undergraduate science and math educators
- Diverse institutions
- MCAT leadership (a division of AAMC) closely involved
- Good source of guidance for Introductory Physics for the Life Sciences

Structure of The 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.

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:**

  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 physics 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 Objective 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.

AAMC MR5
MCAT Review and Revision

- Built on the SFFP recommendations about preparation for medical school.
- Content decided by "importance survey" of medical school faculty, medical students, residents… combined with "frequently taught survey" of undergraduate natural science faculty.

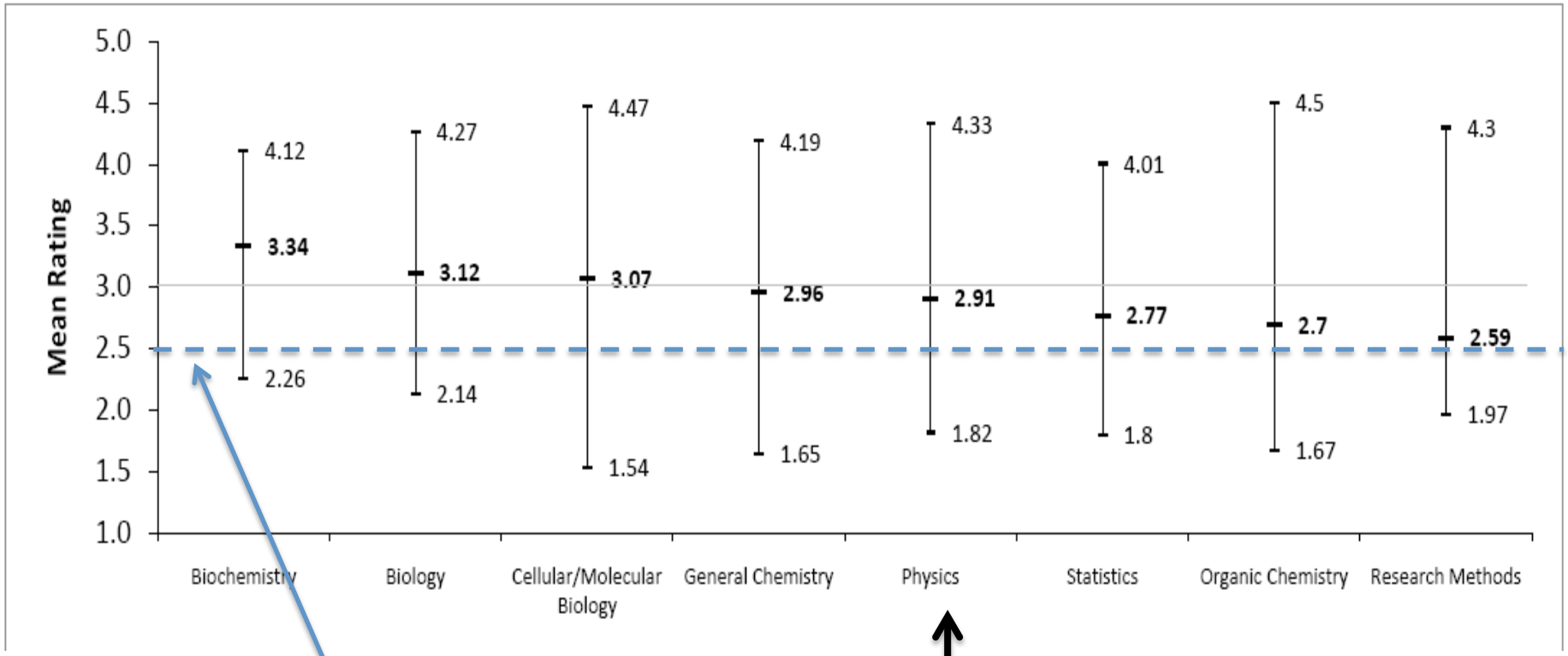
Natural sciences topics rated highly in importance in preparation for medical school?

Administered 5 science surveys:

- Biology
- Chemistry (includes both General and Organic)
- Physics
- Biochemistry
- Cellular/Molecular Biology

➢ Limitations of the survey

Science Survey Results



Current MCAT cut-off

Physics

Physics Topics That Were Rated Very Highly
> 3.0

- Units and dimensions
- Mass, length, time, role of experiment and measurement
- Error (uncertainty) analysis
- Transport Processes – diffusion, osmosis, etc.

- Graphing Techniques
- Translational motion
- Sound
- Kinetic Theory and Ideal Gas Laws
- Fluids
- Circuit elements (batteries, capacitors, dielectrics, resistors,…)
- Atomic Nucleus
- Feedback and Control (descriptive)
- Statistical Physics (statistical distributions, fluctuations and noise)

- = 4.0 or higher (greater than any biochemistry topic)

Physics Topics with Relatively Low Ratings < 2.5

- Momentum
- Rotational motion
- Circuits (Kirchhoff's Rules, Wheatstone bridge, potentiometer and voltage dividers, power in circuits)
- Magnetism (magnetic materials, orbits of charged particles in magnetic fields, general sources of B fields)
- Electromagnetic Induction
- Alternating Current Circuits

The Revised MCAT

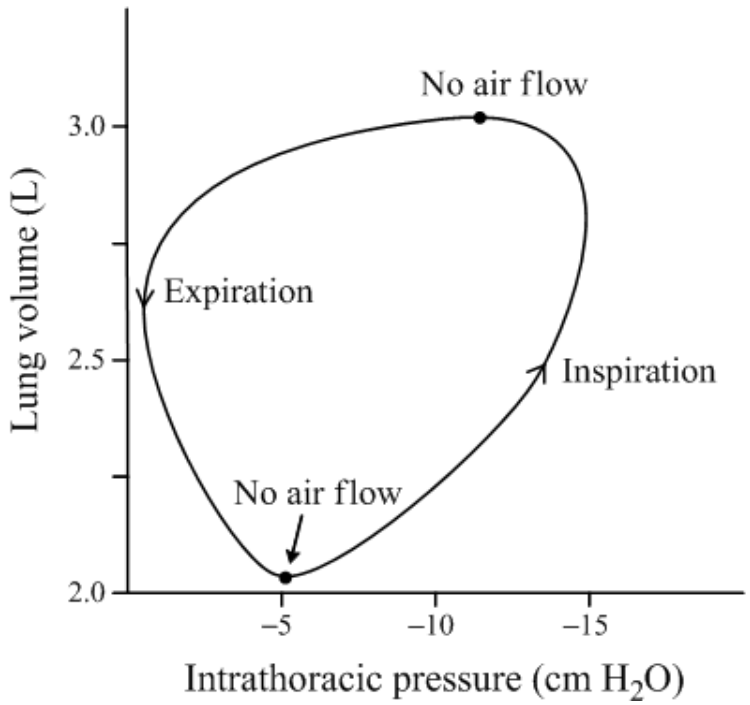
- Remove the writing sample – not used by medical school admissions committees
- Lengthen the exam slightly (return to the length used in the early 90s)
- Four sections:
  - Physical and Chemical Principles of Biological Systems
  - Biochemical and Biological Principles of Living Systems
  - Psychological, Social, and Biological Foundations of Behavior (as they affect health and disease)
  - Critical Reasoning

MCAT Scientific Inquiry and Reasoning Skills

- **Skill 1:** Knowledge of Scientific Concepts and Principles
- **Skill 2:** Scientific Reasoning and Evidence-based Problem Solving
- **Skill 3:** Reasoning About the Design and Execution of Research
- **Skill 4:** Data-based and Statistical Reasoning

MCAT Passage Questions

- Eventually most of the MCAT questions will be based on passages giving background information
- The questions associated with the passage will have the students use the SIRS to answer questions based on the passage.



The pressure and volume changes that occur during a cycle of breathing are illustrated graphically in the figure shown.

What does the area within the curve represent?

A. Work done

B. Oxygen removed

C. Lung volume change

D. Air pressure change

Challenges for Undergraduate Faculty

- Assure that your courses help students meet the SFFP and other competencies
- Sharpen the focus of undergraduate physics courses for life science students: not everything in the standard introductory physics course is relevant to life science students
- Work with other STEM colleagues to streamline and focus the pre-health curriculum
- Work with pre-health profession advisors as medical schools change admission requirements

Common Themes
NGSS, AP, MCAT

- Emphasis on competencies: what you should know and what you should be able to do with that knowledge
- Science practices: students should learn science using the same practices scientists use as they do science. (Be explicit about those practices.) And they should be able to apply their knowledge using the practices.

Recommendations

- Make clear the disciplinary core ideas and cross-cutting concepts as they appear in physics courses
- Make explicit our use of science and engineering practices
- For introductory physics for the life sciences, choose content that supports students' understanding of living systems (take some biologists to lunch)

Further Information

- NGSS: www.nextgenscience.org
- "Google" AP Physics 1
- "Physics and the Revised MCAT," in May 2014, Am. J. Phys.
- Introductory Physics for the Life Sciences Conference, March 14-16, 2014, Washington, DC
- Information about IPLS available on comPADRE.org