

**MCAT**  
Medical College  
Admission Test



# MCAT 2015

A Better Test for Tomorrow's Doctors

**Preview Guide  
for the MCAT<sup>2015</sup> Exam  
(Second Edition)**  
September 2012

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This is the second edition of the *Preview Guide to the MCAT<sup>2015</sup> Exam*. The original guide was published in November 2011. For more information about the MCAT<sup>2015</sup> exam, please see the MCAT<sup>2015</sup> website [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

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## Introduction

The *Preview Guide for the MCAT<sup>2015</sup> Exam (Second Edition)* is a blueprint for the exam that will be introduced in spring 2015<sup>1</sup>. It describes the new exam's content and format. It also lists and discusses the new exam's conceptual framework — which is organized around foundational concepts, content categories, and scientific inquiry and reasoning skills. It provides sample test questions, and includes information about products and services that are designed to help you and others prepare for the MCAT<sup>2015</sup> exam.

While the *Preview Guide for the MCAT<sup>2015</sup> Exam (Second Edition)* is written for you, the prospective MCAT examinee, the information it provides is likely to be useful to pre-health advisors, other baccalaureate faculty, medical school admission officers, and medical school faculty. The information provided in this guide will help you formulate a strategy to prepare for the exam. It will help pre-health advisors and other baccalaureate faculty familiarize themselves with the new exam and what they can do to help you prepare. And, it will provide medical school admissions officers and faculty with important and valuable information to help them interpret their applicants' scores.

The *Preview Guide for the MCAT<sup>2015</sup> Exam (Second Edition)* answers the following questions:

- Why is the MCAT exam changing?
- When will the new exam first be administered?
- How many sections does the new exam include?
- What does each section measure?
- How does the new exam test knowledge and skills in the natural, social, and behavioral sciences?
- How does it test critical analysis and reasoning skills?
- What does the *Biological and Biochemical Foundations of Living Systems* section test?
- What does the *Chemical and Physical Foundations of Biological Systems* section test?
- What does the *Psychological, Social, and Biological Foundations of Behavior* section test?
- What does the *Critical Analysis and Reasoning Skills* section test?
- What products and services are available to help you prepare?
- What products and services are available for pre-health advisors and other baccalaureate faculty?

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<sup>1</sup> This is the *Preview Guide for the MCAT<sup>2015</sup> Exam (Second Edition)*. This edition responds to questions from readers since the first release in November 2011 and includes new information on some of the content outlines. Specifically, the changes include (1) updated descriptions of the Scientific Inquiry and Reasoning Skills (Chapter 3); (2) a description of the mathematical, statistical, and research concepts you are expected to know (Chapter 3); (3) updated descriptions and content lists in the *Biological and Biochemical Foundations of Living Systems* section (Chapter 4), *Chemical and Physical Foundations of Biological Systems* section (Chapter 5), and *Psychological, Social, and Biological Foundations of Behavior* section (Chapter 6); (4) updated information about the percentages of questions that will test each foundational concept and discipline on the three natural, behavior, and social sciences sections; and (5) updated descriptions of the analysis and reasoning skills tested by the *Critical Analysis and Reasoning Skills* section (Chapter 7). Additional information about the products and services available for students, advisors, and other faculty also are included in this version.

- Where can additional information about the MCAT<sup>2015</sup> exam be found?

## Chapter 1: Why is the MCAT Exam Changing?

Science advances rapidly, the health care system is transforming in big ways, our population is becoming more diverse every day — and tomorrow’s doctors need to be prepared. Those factors play a major role in shaping what students learn in medical school and what they need to know when they begin.

A comprehensive review of the Medical College Admission Test<sup>®</sup> (MCAT<sup>®</sup>) was just completed by the Association of American Medical Colleges (AAMC) and its 21-member advisory committee. After three years of hard work, the committee proposed a set of [recommendations](#) for the MCAT<sup>2015</sup> exam, which you can read about on the AAMC website: [www.aamc.org/mr5](http://www.aamc.org/mr5).

The recommended changes preserve what works about the current MCAT exam, eliminate what isn’t working, and enrich the exam by giving attention to the concepts tomorrow’s doctors will need. These concepts were identified by soliciting input from several blue-ribbon panels and advisory groups, and through extensive research including surveys of over 2,700 baccalaureate and medical school faculty, residents, current medical students, and medical school admissions and academic affairs officers.<sup>2</sup>

What is different and exciting about the new exam?

- The natural sciences sections of the MCAT<sup>2015</sup> exam reflect recent changes in medical education. They test the concepts in biology, general and organic chemistry, biochemistry, and physics that medical school faculty rate as most important to entering students’ success. Though undergraduate course offerings differ by institution, these concepts are covered in many undergraduate schools in introductory sequences in biology, general chemistry, organic chemistry, and physics and in first-semester biochemistry courses.
- The MCAT<sup>2015</sup> exam includes a section on the social and behavioral sciences: *Psychological, Social, and Biological Foundations of Behavior*. This section tests your knowledge of important introductory psychology and sociology concepts, as well as the introductory biology concepts that relate to mental processes and behavior. The addition of this section to the exam recognizes the importance of socio-cultural and behavioral determinants of health and health outcomes.
- The *Critical Analysis and Reasoning Skills* section asks you to analyze, evaluate, and apply information provided by passages from a wide range of social sciences and humanities disciplines. It does not require specific knowledge of these disciplines, but it tests the analysis and reasoning skills you need for medical school, and may prompt you to read broadly as you prepare. Along with many others, passages about ethics and philosophy, cultural studies, and population health are included.

<sup>2</sup> In fall 2009, the AAMC’s MR5 committee surveyed over 1,000 medical school faculty, residents, and medical students to learn which natural sciences concepts entering students need to know in order to succeed in medical school. Then, in winter 2009, they gathered information from over 1,000 baccalaureate faculty to learn how these concepts are covered in the undergraduate curriculum. Minority-serving schools were overrepresented in the data collection. The online surveys asked respondents about content in the following disciplines: Biology (including genetics), General Chemistry, Organic Chemistry, Physics, Biochemistry, Cellular/Molecular Biology, Research Methods, and Statistics. Each disciplinary survey included a list of topics and subtopics from that discipline. If you would like to know more about the results of these studies, please visit the MR5 website: [www.aamc.org/mr5](http://www.aamc.org/mr5).

If you would like to know more about the review process and the timeline for development of the MCAT<sup>2015</sup> exam, please visit the AAMC website: [www.aamc.org/mr5](http://www.aamc.org/mr5). For detailed information about the new exam — keep reading.

## Chapter 2: What will the MCAT<sup>2015</sup> Exam Measure?

The MCAT<sup>2015</sup> exam has four test sections:

- 1) *Biological and Biochemical Foundations of Living Systems*,
- 2) *Chemical and Physical Foundations of Biological Systems*,
- 3) *Psychological, Social, and Biological Foundations of Behavior*, and
- 4) *Critical Analysis and Reasoning Skills*

Scores are reported on a scale similar to the current 1-15 scale, and a separate score is recorded for each of the four test sections: four sections, four scores.

The *Biological and Biochemical Foundations of Living Systems* and the *Chemical and Physical Foundations of Biological Systems* sections are designed to:

- test introductory-level biology, organic and inorganic chemistry, and physics concepts;
- test biochemistry concepts at the level taught in many colleges and universities in first-semester biochemistry courses;
- test cellular/molecular biology topics at the level taught in many colleges and universities in introductory biology sequences;
- target basic research methods and statistics concepts described by many baccalaureate faculty as important to success in introductory science courses; and
- require you to demonstrate your scientific inquiry and reasoning, research methods, and statistics skills as applied to the natural sciences.

The *Psychological, Social, and Biological Foundations of Behavior* section is designed to:

- test your knowledge and use of the concepts in psychology, sociology, and biology that provide a solid foundation for learning in medical school about the behavioral and socio-cultural determinants of health;
- target concepts taught at many colleges and universities in one-semester introductory psychology and one-semester introductory sociology courses;
- target biology concepts that relate to mental processes and behavior that are taught at many colleges and universities in introductory biology;
- target basic research methods and statistics concepts described by many baccalaureate faculty as important to success in introductory science courses; and
- require you to demonstrate your scientific inquiry and reasoning, research methods, and statistics skills as applied to the social and behavioral sciences.



The *Critical Analysis and Reasoning Skills* section is designed to:

- test your comprehension, analysis, and reasoning skills by asking you to critically analyze information provided in reading passages;
- include content from ethics, philosophy, cultural studies, population health, and a wide range of social sciences and humanities disciplines; and
- provide all of the information needed to answer questions in the passages.

Table 1 on the next page provides a summary of the four sections of the MCAT<sup>2015</sup> exam, including the approximate number of questions and approximate number of minutes allotted to complete each section.

<b>Table 1: Summary of the MCAT<sup>2015</sup> exam</b>	<b>Approximate number of items</b>	<b>Approximate number of minutes</b>
<p><b><i>Biological and Biochemical Foundations of Living Systems</i></b></p> <p>This section asks you to combine your knowledge of foundational concepts in the biological and biochemical sciences with your scientific inquiry, reasoning, and research and statistics skills to solve problems that demonstrate readiness for medical school.</p> <p>Understanding the processes unique to living organisms, such as growing and reproducing, maintaining a constant internal environment, acquiring materials and energy, sensing and responding to environmental changes, and adapting, is important to the study of medicine. You will be tested on your knowledge of how cells and organ systems within an organism act both independently and in concert to accomplish these processes, as well as your ability to reason about these processes at various levels of biological organization within a living system.</p>	67	95
<p><b><i>Chemical and Physical Foundations of Biological Systems</i></b></p> <p>This section asks you to combine your knowledge of foundational concepts in the chemical and physical sciences with your scientific inquiry, reasoning, and research and statistics skills to solve problems that demonstrate readiness for medical school.</p> <p>Understanding the mechanical, physical, and biochemical functions of tissues, organs, and organ systems is important to the study of medicine. You will be tested on your knowledge of the basic chemical and physical principles that underlie the mechanisms operating in the human body, and your ability to apply an understanding of these general principles to living systems.</p>	67	95
<p><b><i>Psychological, Social, and Biological Foundations of Behavior</i></b></p> <p>This section tests your knowledge and use of the concepts in psychology, sociology, biology, research methods, and statistics that provide a solid foundation for learning in medical school about the behavioral and socio-cultural determinants of health and health outcomes.</p> <p>Understanding the behavioral and socio-cultural determinants of health is important to the study of medicine. You will be tested on your knowledge of the ways in which psychological, social, and biological factors influence perceptions and reactions to the world; behavior, and behavior change; what people think about themselves and others; the cultural and social differences that influence well-being; and the relationships between social stratification, access to resources, and well-being.</p>	67	95
<p><b><i>Critical Analysis and Reasoning Skills</i></b></p> <p>This section asks you to critically analyze information from a wide range of social sciences and humanities disciplines. Specific knowledge of these disciplines is <i>not</i> required for this section; all of the information you will need appears in the passages provided. Among the areas from which content is drawn are ethics and philosophy, cultural studies, and population health.</p>	60	90

## Chapter 3: How will the MCAT<sup>2015</sup> Exam Test Knowledge and Skills in the Natural, Social, and Behavioral Sciences?

This chapter describes the conceptual framework for the natural, social, and behavioral sciences sections of the MCAT<sup>2015</sup> exam. (The *Critical Analysis and Reasoning Skills* section is described in Chapter 7 of the *Preview Guide for the MCAT<sup>2015</sup> Exam*.)

The two natural sciences sections and the *Psychological, Social, and Behavioral Foundations of Behavior* section of the new exam are organized around foundational concepts or “big ideas” in the sciences. They reflect current research about the most effective ways for students to learn and use science, emphasizing deep knowledge of the most important scientific concepts over shallow knowledge of many discrete scientific facts. Leaders in science education say that some of the most important foundational concepts in the sciences ask students to bring together information from different disciplines. And they ask students to combine their scientific knowledge with their inquiry and reasoning skills. The blueprints for the MCAT<sup>2015</sup> exam are based on the recommendations from this research.<sup>3</sup>

The natural, social, and behavioral sciences sections of the test are organized around three dimensions:

- 1) **Foundational Concepts** – the “big ideas” in the sciences that provide the foundation for learning in medical school;
- 2) **Content Categories** – the topics and subtopics that are needed to understand foundational concepts; and
- 3) **Scientific Inquiry and Reasoning Skills** – the inquiry and reasoning skills that are required to solve scientific problems.

### Foundational Concepts and Content Categories

The two natural science sections of the MCAT<sup>2015</sup> exam and the *Psychological, Social, and Behavioral Foundations of Behavior* section test ten foundational concepts in all:<sup>4</sup>

- the *Biological and Biochemical Foundations of Living Systems* section is organized around Foundational Concepts 1-3;
- the *Chemical and Physical Foundations of Living Systems* test is organized around Foundational Concepts 4-5, and
- the *Psychological, Social, and Behavioral Foundations of Behavior* section is organized around Foundational Concepts 6-10.

<sup>3</sup> See the *Scientific Foundations for Future Physicians* report (2009), *AAAS Vision and Change Report* (2009), *Advanced Placement Biology Content Outline* (2010), the *Science Framework for the 2011 NAEP* (2010), *NAS Science Standards public comment draft* (2010), and other national reports.

<sup>4</sup> Foundational Concepts 1-3 align with entering medical student competencies 5-7 described by the *Scientific Foundations for Future Physicians* Committee. Foundational Concept 1 also includes ideas from entering medical student competency 8. Foundational Concepts 4 and 5 align with entering medical student competencies 3 and 4.

Next we provide descriptions of the ten foundational concepts, along with the content categories that support them. This is followed by descriptions of the four scientific inquiry and reasoning skills you will be asked to demonstrate on the exam. Following these descriptions, we describe how the foundational concepts, content categories, and scientific inquiry and reasoning skills come together to test your readiness for medical school.

More detail about the foundational concepts, content categories, and skills along with example test questions are provided later, in the individual chapter for each test section.

### ***Biological and Biochemical Foundations of Living Systems (See Chapter 4)***

**Foundational Concept 1:** *Biomolecules have unique properties that determine how they contribute to the structure and function of cells, and how they participate in the processes necessary to maintain life.*

The content categories for this foundational concept include:

- 1A. Structure and function of proteins and their constituent amino acids
- 1B. Transmission of genetic information from the gene to the protein
- 1C. Transmission of heritable information from generation to generation and the processes that increase genetic diversity
- 1D. Principles of bioenergetics and fuel molecule metabolism

**Foundational Concept 2:** *Highly-organized assemblies of molecules, cells, and organs interact to carry out the functions of living organisms.*

The content categories for this foundational concept include:

- 2A. Assemblies of molecules, cells, and groups of cells within single cellular and multicellular organisms
- 2B. The structure, growth, physiology, and genetics of prokaryotes and viruses
- 2C. Processes of cell division, differentiation, and specialization

**Foundational Concept 3:** *Complex systems of tissues and organs sense the internal and external environments of multicellular organisms, and through integrated functioning, maintain a stable internal environment within an ever-changing external environment.*

The content categories for this foundational concept include:

- 3A. Structure and functions of the nervous and endocrine systems and ways in which these systems coordinate the organ systems
- 3B. Structure and integrative functions of the main organ systems

### ***Chemical and Physical Foundations of Biological Systems (See Chapter 5)***

**Foundational Concept 4:** *Complex living organisms transport materials, sense their environment, process signals, and respond to changes using processes understood in terms of physical principles.*

The content categories for this foundational concept include:

- 4A. Translational motion, forces, work, energy, and equilibrium in living systems
- 4B. Importance of fluids for the circulation of blood, gas movement, and gas exchange
- 4C. Electrochemistry and electrical circuits and their elements
- 4D. How light and sound interact with matter
- 4E. Atoms, nuclear decay, electronic structure, and atomic chemical behavior

**Foundational Concept 5:** *The principles that govern chemical interactions and reactions form the basis for a broader understanding of the molecular dynamics of living systems.*

The content categories for this foundational concept include:

- 5A. Unique nature of water and its solutions
- 5B. Nature of molecules and intermolecular interactions
- 5C. Separation and purification methods
- 5D. Structure, function, and reactivity of biologically-relevant molecules
- 5E. Principles of chemical thermodynamics and kinetics

***Psychological, Social, and Biological Foundations of Behavior (See Chapter 6)***

**Foundational Concept 6:** *Biological, psychological, and socio-cultural factors influence the ways that individuals perceive, think about, and react to the world.*

The content categories for this foundational concept include:

- 6A. Sensing the environment
- 6B. Making sense of the environment
- 6C. Responding to the world

**Foundational Concept 7:** *Biological, psychological, and socio-cultural factors influence behavior and behavior change.*

The content categories for this foundational concept include:

- 7A. Individual influences on behavior
- 7B. Social processes that influence human behavior
- 7C. Attitude and behavior change

**Foundational Concept 8:** *Psychological, socio-cultural, and biological factors influence the way we think about ourselves and others.*

The content categories for this foundational concept include:

- 8A. Self-identity
- 8B. Social thinking
- 8C. Social interactions

**Foundational Concept 9:** *Cultural and social differences influence well-being.*

The content categories for this foundational concept include:

- 9A. Understanding social structure
- 9B. Demographic characteristics and processes

**Foundational Concept 10:** *Social stratification and access to resources influence well-being.*

The content category for this foundational concept is:

- 10A. Social inequality

## Scientific Inquiry and Reasoning Skills<sup>5</sup>

Again, MCAT<sup>2015</sup> questions will ask you to combine your scientific knowledge with your scientific inquiry and reasoning skills. You will be asked to demonstrate four scientific inquiry and reasoning skills on the exam. The same four skills will be tested on the two natural science sections and on the *Psychological, Social, and Biological Foundations of Behavior* section. These skills are important because they are skills that you will need to demonstrate in medical school. They also will be important to your work as a practicing physician. These four skills are skills that natural and social scientists rely on to advance their work. They are:

### Knowledge of Scientific Concepts and Principles

- Demonstrating understanding of scientific concepts and principles
- Identifying the relationships between closely-related concepts

### Scientific Reasoning and Problem Solving

- Reasoning about scientific principles, theories, and models
- Analyzing and evaluating scientific explanations and predictions

### Reasoning about the Design and Execution of Research

- Demonstrating understanding of important components of scientific research
- Reasoning about ethical issues in research

### Data-Based and Statistical Reasoning

- Interpreting patterns in data presented in tables, figures, and graphs
- Reasoning about data and drawing conclusions from them

Demonstrating these skills on the exam will allow you to show that you understand scientific concepts, that you know how to use scientific principles to solve problems, and, like other scientists, that you know how to ‘do’ science by using appropriate scientific methodology and working with scientific data.

The next section of this chapter describes the four scientific inquiry and reasoning skills shown in the figure and provides detail about the ways in which you will be asked to demonstrate them. Example questions can be found at the end of this chapter and chapters 4, 5, and 6. For each of these questions, we indicate the scientific inquiry and reasoning skill that is being tested.

<sup>5</sup> These skills are based, in part, on a number of national science reports/documents including (but not limited to): *Scientific Foundation for Future Physicians* report (2009), *AAAS Vision and Change* report (2009), Advanced Placement biology content outline (2010), the science framework for the 2011 NAEP (2010), NAS science standards public comment draft (2010).

### ***Skill 1: Knowledge of Scientific Concepts and Principles***

The types of questions in this skill category will ask you to demonstrate your knowledge of the ten foundational concepts and the topics listed with them in the previous section of this chapter. These questions will ask you to recognize, recall, define, and relate basic concepts in the natural and social sciences. The concepts and scientific principles may be represented in words, graphs, tables, diagrams, or formulas.

As you work on these questions, you may be asked to recognize a scientific fact or define a concept. Or you may be asked to apply a scientific principle to a problem. Questions may ask you to identify the relationships between closely-related concepts or relate verbal to graphic representations of science content. They may ask you to identify examples of observations that illustrate scientific principles. Questions may ask you to recognize a scientific concept shown in a diagram or represented in a graph. Or they may give you a mathematical equation and ask you use it to solve a problem.

Questions that test this skill will ask you to show that you understand scientific concepts and principles by, for example:

- Recognizing correct scientific principles
- Identifying the relationships among closely-related concepts
- Identifying the relationships between different representations of concepts (e.g., verbal, symbolic, graphic)
- Identifying examples of observations that illustrate scientific principles
- Using mathematical equations to solve problems



## ***Skill 2: Scientific Reasoning and Problem-solving***

Questions that test scientific reasoning and problem-solving skills differ from questions in the previous category by asking you to use your scientific knowledge to solve problems in the natural and social sciences.

As you work on questions that test these skills, you may be asked to use scientific theories to explain observations or make predictions about natural or social phenomena. Questions may ask you to judge the credibility of scientific explanations or to evaluate arguments about cause and effect. Or they may ask you to use scientific models and observations to draw conclusions. They may ask you to recognize scientific findings that call a theory or model into question. Questions in this category may ask you to look at pictures or diagrams and draw conclusions from them. Or they may ask you to determine and then use scientific formulas to solve problems.

Questions that test this skill will ask you to show that you can use scientific principles to solve problems by, for example:

- Reasoning about scientific principles, theories, and models
- Analyzing and evaluating scientific explanations and predictions
- Evaluating arguments about causes and consequences
- Bringing together theory, observations, and evidence to draw conclusions
- Recognizing scientific findings that challenge or invalidate a scientific theory or model
- Determining and using scientific formulas to solve problems

### ***Skill 3: Reasoning about the Design and Execution of Research***<sup>6</sup>

Questions that test reasoning about the design and execution of research will ask you to show that you can ‘do’ science by demonstrating your scientific inquiry skills. They will ask you to demonstrate your understanding of important components of scientific methodology. These questions will ask you to demonstrate your knowledge of the ways in which natural and social scientists conduct research to test and extend scientific knowledge.

As you work on these questions, you may be asked to show how scientists use theory, past research findings, and observations to ask testable questions and pose hypotheses. Questions that test these skills may ask you to reason about the ways in which scientists gather data from samples of members of the population about which they’d like to draw inferences. They may ask you to identify how scientists manipulate and control variables to test their hypotheses. Questions may ask you to reason about the ways in which scientists take measurements and record results. These questions may ask you to recognize faulty research logic or point out the limitations of the research studies that are described. Or they may ask you to identify factors that might confuse the inferences you can draw from the results.

These questions may ask you to demonstrate your knowledge of the ways in which scientists draw inferences from their results about associations between variables or causal relationships between them. Questions that test these skills may ask you to examine evidence from a scientific study and point out statements that go beyond the evidence. Or they may ask you to suggest alternative explanations for the same data.

These questions also may ask you to demonstrate and use your understanding of the ways in which scientists adhere to ethical guidelines to protect the rights of research participants, the integrity of their work, and the interests of research consumers.

Questions that test this skill will ask you to use your knowledge of important components of scientific methodology by, for example:

- Identifying the role of theory, past findings, and observations in scientific questioning
- Identifying testable research questions and hypotheses
- Distinguishing between samples and populations and results that support generalizations about populations
- Identifying independent and dependent variables
- Reasoning about the features of research studies that suggest associations between variables or causal relationships between them (e.g., temporality, random assignment)
- Identifying conclusions that are supported by research results
- Determining the implications of results for real-world situations
- Reasoning about ethical issues in scientific research

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<sup>6</sup> Scientific Inquiry and Reasoning Skill 3 aligns with entering medical school competency 2 described by the Scientific Foundations for Physicians Committee.

### ***Skill 4: Data-based and Statistical Reasoning***<sup>7</sup>

Like questions in the third category, questions that test the fourth skill will ask you to show that you can ‘do’ science, this time by demonstrating your data-based and statistical-reasoning skills. Questions that test this skill will ask you to reason with data. They will ask you to read and interpret results using tables, graphs, and charts. These questions will ask you to demonstrate that you can identify patterns in data and draw conclusions from evidence.

Questions that test these skills may ask you to demonstrate your knowledge of the ways in which natural and social scientists use measures of central tendency and dispersion to describe their data. These questions may ask you to demonstrate your understanding of the ways in which scientists think about random and systematic errors in their experiments and datasets. They may ask about the ways that scientists think about uncertainty and the implications of uncertainty for statistical testing and the inferences they can draw from their data. These questions may ask you to show how scientists use data to make comparisons between variables or explain relationships between them or make predictions. They may ask you to use data to answer research questions or draw conclusions.

Questions that test this skill will ask you to use your knowledge of data-based and statistical reasoning by, for example:

- Using, analyzing, and interpreting data in figures, graphs, and tables
- Evaluating whether representations make sense for particular scientific observations and data
- Using measures of central tendency (mean, median, and mode) and measures of dispersion (range, inter-quartile range, and standard deviation) to describe data
- Reasoning about random and systematic error
- Reasoning about statistical significance and uncertainty (i.e., interpreting statistical significance levels, interpreting a confidence interval)
- Using data to explain relationships between variables or make predictions
- Using data to answer research questions and draw conclusions

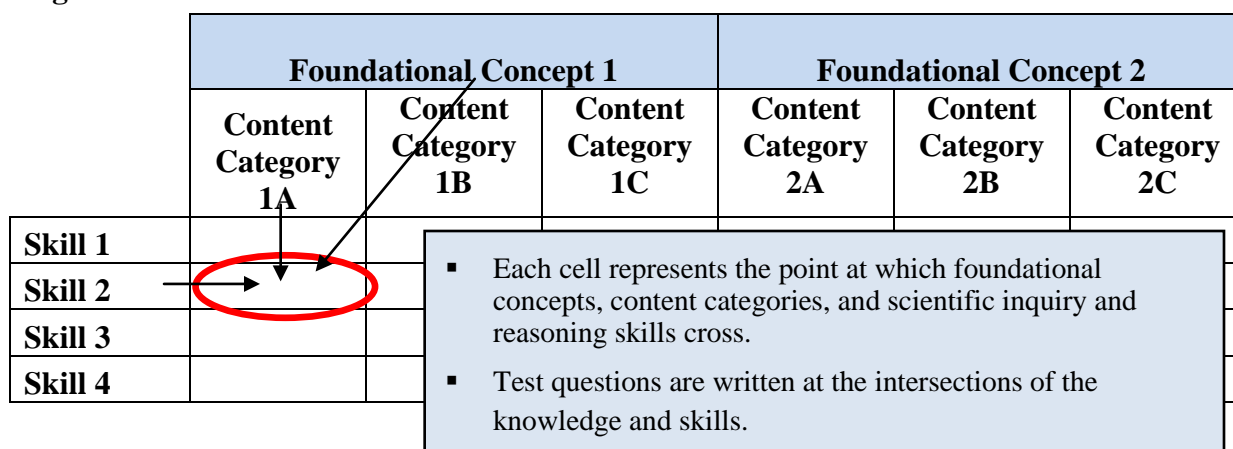
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<sup>7</sup> Scientific Inquiry and Reasoning Skill 4 aligns with entering medical school competency 1 described by the Scientific Foundations for Physicians Committee.

## How the Foundational Concepts, Content Categories, and Skills Fit Together

As mentioned previously, the MCAT<sup>2015</sup> exam asks you to solve problems by combining your knowledge of foundational concepts with your scientific inquiry and reasoning skills. Figure 1 illustrates how foundational concepts, content categories, and scientific inquiry and reasoning skills intersect to create test items.

Figure 1.



We are going to use an example from the *Biological and Biochemical Foundations of Living Systems* section to illustrate how this works. In the following example, you are asked to solve a scientific problem by combining your knowledge of the digestive system with your data-based and statistical reasoning skills. It combines:

- Foundational Concept 3:** Complex systems of tissues and organs sense the internal and external environments of multicellular organisms, and through integrated functioning, maintain a stable internal environment within an ever-changing external environment.
- Content Category 3B:** Structure and integrative functions of the main organ systems (See Chapter 4 for complete list of topics and subtopics.)

**EXAMPLE**

**Digestive System (BIO)** ← **Topic**

- Ingestion ← **Subtopic**
  - Saliva as lubrication and source of enzymes
  - Ingestion, esophagus, transport function
- Stomach
  - Storage and churning of food
  - Low pH, gastric juice, mucal protection against self-destruction
  - Production of digestive enzymes, site of digestion
  - Structure (gross)

- Scientific Inquiry and Reasoning Skill 4:** Data-based and statistical reasoning skills

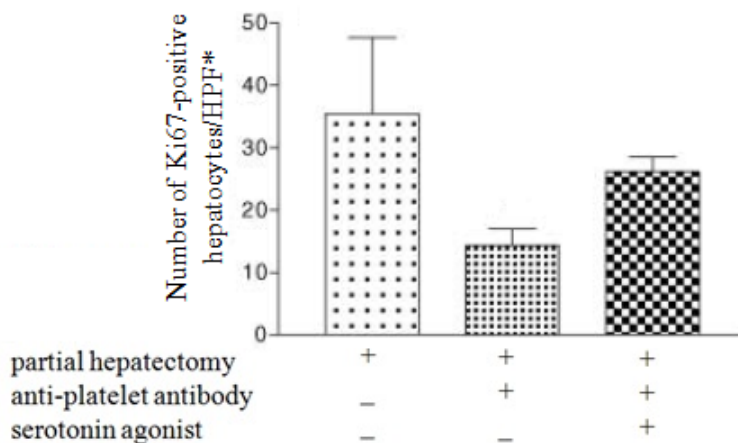
## Sample Passage<sup>8</sup>

In many animals, including mice and humans, the liver quickly regenerates to its original size after a partial hepatectomy in which two-thirds of the organ is removed. Hepatocyte proliferation in response to this surgery is significantly reduced in mice with inadequate platelet activity or number.

Platelets carry 95% of blood serotonin, which is synthesized from tryptophan and secreted by endocrine cells in the lining of the gastrointestinal tract. Researchers experimentally tested the hypothesis that platelet serotonin is responsible for the platelets' positive effect on hepatocyte proliferation. The number of hepatocytes expressing the Ki67 protein, which is detected exclusively in the nuclei of proliferating cells, was used as a measure of liver regeneration.

### Experiment 1

Wild-type mice were treated with an anti-platelet antibody that destroys 90% of their circulating platelets; a subset of these mice was also injected with a serotonin agonist, which mimics serotonin's actions on its receptors (Figure 1).

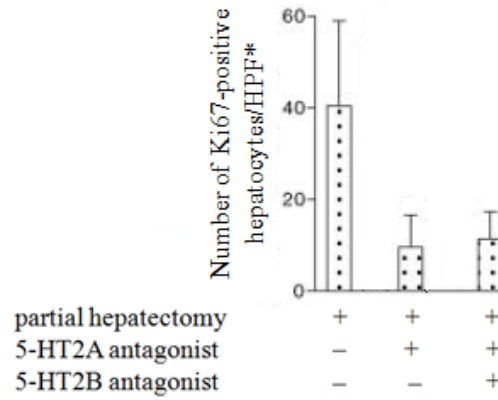


**Figure 1.** Effects of platelet depletion and serotonin agonist on hepatocyte proliferation (\*HPF = high power field)

<sup>8</sup> This sample passage and question have not followed the same review and field-test procedures as do operational test materials.

### Experiment 2

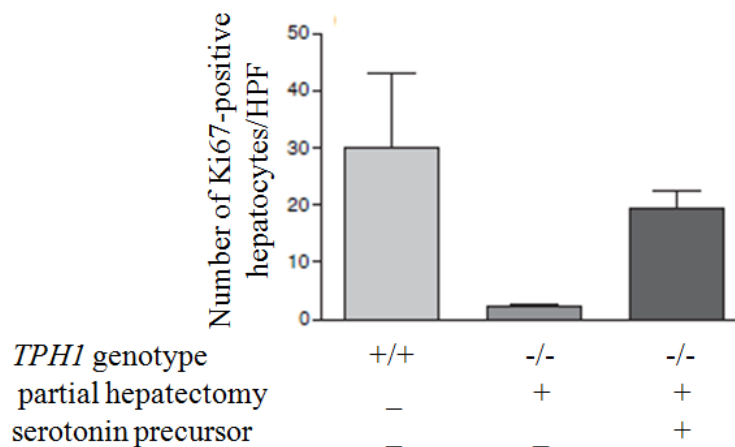
Wild-type mice were treated with antagonists of the serotonin receptors 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub>, receptors that are expressed on hepatocytes and other cells types (Figure 2).



**Figure 2.** Effects of serotonin receptor antagonists on hepatocyte proliferation

### Experiment 3

This experiment used *TPH1*<sup>-/-</sup> mice, which lack the gastrointestinal cell enzyme TPH1 necessary to make circulating serotonin; some of the *TPH1*<sup>-/-</sup> mice were injected with a serotonin biosynthetic precursor that could be converted into serotonin and then imported into platelets (Figure 3)



**Figure 3.** Effects of *TPH1*<sup>-/-</sup> genotype and serotonin precursor on hepatocyte proliferation

Source: Adapted from a paper by M. Lesurtel, et al., ©2006 by the American Association for the Advancement of Science.

## Sample Question

- 1) Which finding, when combined with the data in the passage, is most likely to lead researchers to conclude that the 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub> receptor subtypes mediate serotonin-dependent liver regeneration?
- Administration of 5-HT<sub>2A</sub> receptor agonist resulted in reduced Ki67 staining.
  - RNA for seven different receptor subtypes was detectible in naïve liver tissue.
  - Up-regulation of 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub> was observed during periods of peak hepatocyte proliferation.
  - Administration of 5-HT<sub>2C</sub> and 5-HT<sub>3</sub> receptor antagonists reduced the number of Ki67-positive cells.

The answer to this question is: C. On the operational exam, passage sets include at least four questions. Refer to Chapter 4 for additional sample questions for this passage. You will also find in Chapter 4 additional passages and questions for the *Biological and Biochemical Foundations of Living Systems* section.

### General Mathematical Concepts and Techniques

Before you look at the sample passages and questions in the following chapters (4 - 6), it is important for you to know that questions on the natural and social sciences sections will ask you to use certain mathematical concepts and techniques. As the descriptions of the scientific inquiry and reasoning skills suggest, some questions will ask you to analyze and manipulate scientific data. These questions will ask you to show that you can:

- Recognize and interpret linear, semilog, and log-log scales and calculate slopes from data found in figures, graphs, and tables
- Demonstrate a general understanding of significant digits and the use of reasonable numerical estimates in performing measurements and calculations
- Use metric units, including conversion of units within the metric system, conversions between metric and English units (conversion factors will be provided when needed); dimensional analysis (using units to balance equations)
- Perform arithmetic calculations involving the following: probability, proportion, ratio, percentage, square-root estimations
- Demonstrate a general understanding (Algebra II-level) of exponentials and logarithms (natural and base ten), scientific notation, solving simultaneous equations
- Demonstrate a general understanding of the following trigonometric concepts: definitions of basic (sine, cosine, tangent) and inverse ( $\sin^{-1}$ ,  $\cos^{-1}$ ,  $\tan^{-1}$ ) functions;  $\sin$  and  $\cos$  values of  $0^\circ$ ,  $90^\circ$ , and  $180^\circ$ ; relationships between the lengths of sides or right triangles containing angles of  $30^\circ$ ,  $45^\circ$ , and  $60^\circ$
- Demonstrate a general understanding of vector addition and subtraction, right-hand rule (knowledge of dot and cross products is not required)

Note also that an understanding of Calculus is **NOT** required, and a periodic table will be provided to you during the exam.

## Chapter 4: What will the *Biological and Biochemical Foundations of Living Systems* Section Test?

The *Biological and Biochemical Foundations of Living Systems* section asks you to solve problems by combining your knowledge of biological and biochemical concepts with your scientific inquiry and reasoning skills. This section tests processes that are unique to living organisms, such as growing and reproducing, maintaining a constant internal environment, acquiring materials and energy, sensing and responding to environmental changes, and adapting. It also tests how cells and organ systems within an organism act independently and in concert to accomplish these processes, and asks examinees to reason about these processes at various levels of biological organization within a living system.

### Descriptions of Foundational Concepts and Content Categories

Following are detailed explanations of each foundational concept and related content category tested by the *Biological and Biochemical Foundations of Living Systems* section. To help you prepare for the MCAT<sup>2015</sup> exam, we provide content lists that describe specific topics and subtopics that define each content category for this section. The same content list is provided to item writers who develop the content of the exam. Here is an excerpt from the content list.

**EXAMPLE**

**Metabolism of Fatty Acids and Proteins (BIO, BC) ← Topic**

- Description of fatty acids (BC)
- Digestion, mobilization, and transport of fats ← Subtopic
- Oxidation of fatty acids
  - Saturated fats
  - Unsaturated fats
- Ketone bodies (BC)
- Anabolism of fats (BIO)
- Non-template synthesis: biosynthesis of lipids and polysaccharides (BIO)
- Metabolism of proteins (BIO)

The abbreviations found in parentheses indicate the course(s) in which undergraduate students at many colleges and universities learn about the topics and associated subtopics. The course abbreviations are:

- BC = first-semester biochemistry
- BIO = two-semester sequence of introductory biology
- GC = two-semester sequence of general chemistry
- OC = two-semester sequence of organic chemistry
- PHY = two-semester sequence of introductory physics



In preparing for the MCAT<sup>2015</sup> exam, you will be responsible for learning the topics and associated subtopics at the levels at which they are taught in the courses listed in parentheses. A small number of subtopics have course abbreviations indicated in parentheses. In those cases, you are responsible **only** for learning the subtopics as they are taught in the course(s) indicated.

Using the excerpt above as an example:

- You are responsible for learning about the topic “Metabolism of Fatty Acids and Proteins” at the level at which it is taught in a typical two-semester introductory biology sequence AND in a typical first-semester biochemistry course.
- You are responsible for learning about the subtopics “Anabolism of fats,” “Non-template synthesis: biosynthesis of lipids and polysaccharides,” and “Metabolism of proteins” **only** at the levels at which they are taught in a typical two-semester sequence of introductory biology.
- You are responsible for learning about the subtopics “Description of fatty acids” and “Ketone bodies” **only** at the levels at which they are taught in a typical first-semester biochemistry course.

Remember that course content at your school may differ from course content at other colleges and universities. The topics and subtopics that are described in this chapter and the next two chapters may be covered in courses with different titles than those that are listed. Your pre-health advisor and faculty are important resources for questions about course content.

## *Biological and Biochemical Foundations of Living Systems*

### Foundational Concept 1<sup>9</sup>

Biomolecules have unique properties that determine how they contribute to the structure and function of cells, and how they participate in the processes necessary to maintain life.

The unique chemical and structural properties of biomolecules determine the roles they play in cells. The proper functioning of a living system depends on the many components acting harmoniously in response to a constantly changing environment. Biomolecules are constantly formed or degraded in response to the perceived needs of the organism.

#### Content Categories

- *Category 1A* focuses on the structural and functional complexity of proteins, which is derived from their component amino acids, the sequence in which the amino acids are covalently bonded, and the three-dimensional structures the proteins adopt in an aqueous environment.
- *Category 1B* focuses on the molecular mechanisms responsible for the transfer of sequence-specific biological information between biopolymers which ultimately results in the synthesis of proteins.
- *Category 1C* focuses on the mechanisms that function to transmit the heritable information stored in DNA from generation to generation.
- *Category 1D* focuses on the biomolecules and regulated pathways involved in harvesting chemical energy stored in fuel molecules, which serves as the driving force for all of the processes that take place within a living system.

With these building blocks, medical students will be prepared to learn how the major biochemical energy production pathways are regulated, how the synthesis and degradation of macromolecules functions to maintain health, and how various forms of biochemical dysfunction result in disease.

#### **Please Note**

The topic lists in the *Preview Guide for MCAT<sup>2015</sup>* are preliminary. They will likely be refined (in minor ways) as testing experts continue working on the exam.

The MCAT<sup>2015</sup> website will be updated as information becomes available: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

<sup>9</sup>Foundational Concept 1 aligns with entering medical school competency 5 described by the Scientific Foundations for Future Physicians Committee. It also includes ideas from entering medical school competency 8.

## Content Category 1A: *Structure and function of proteins and their constituent amino acids*

Macromolecules formed from amino acids adopt well-defined, three-dimensional structures with chemical properties that are responsible for their participation in virtually every process occurring within and between cells. The three-dimensional structure of proteins is a direct consequence of the nature of the covalently-bonded sequence of amino acids, their chemical and physical properties, and the way in which the whole assembly interacts with water.

Enzymes are proteins that interact in highly regio- and stereo-specific ways with dissolved solutes. They either facilitate the chemical transformation of these solutes, or allow for their transport innocuously. Dissolved solutes compete for protein-binding sites, and protein conformational dynamics give rise to mechanisms capable of controlling enzymatic activity.

The infinite variability of potential amino acid sequences allows for adaptable responses to pathogenic organisms and materials. The rigidity of some amino acid sequences makes them suitable for structural roles in complex living systems.

Content in this category covers a range of protein behaviors which originate from the unique chemistry of amino acids themselves. Amino acid classifications and protein structural elements are covered. Special emphasis is placed on enzyme catalysis including mechanistic considerations, kinetics, models of enzyme-substrate interaction, and regulation. The topics and subtopics in this category are:

### Amino Acids (BC, OC)

- Description
  - Absolute configuration at the  $\alpha$  position
  - Amino acids as dipolar ions
  - Classifications
    - Acidic or basic
    - Hydrophobic or hydrophilic
- Reactions
  - Sulfur linkage for cysteine and cysteine
  - Peptide linkage: polypeptides and proteins
  - Hydrolysis

#### Please Note

Topics that appear on multiple content lists will be treated differently. Questions will focus on the topics as they are described in the narrative for the content category.

### Protein Structure (BIO, BC, OC)

- Structure
  - 1° structure of proteins
  - 2° structure of proteins
  - 3° structure of proteins; role of proline, cystine, hydrophobic bonding
  - 4° structure of proteins (BIO, BC)
- Conformational stability
  - Denaturing and folding
  - Hydrophobic interactions
  - Solvation layer (entropy) (BC)
- Separation techniques
  - Isoelectric point
  - Electrophoresis

### **Non-Enzymatic Protein Function (BIO, BC)**

- Binding
- Immune system
- Motors

### **Enzyme Structure and Function (BIO, BC)**

- Function of enzymes in catalyzing biological reactions
- Enzyme classification by reaction type
- Reduction of activation energy
- Substrates and enzyme specificity
- Active Site Model
- Induced-fit Model
- Mechanism of catalysis
  - Cofactors
  - Coenzymes
  - Water-soluble vitamins
- Effects of local conditions on enzyme activity

### **Control of Enzyme Activity (BIO, BC)**

- Kinetics
  - General (catalysis)
  - Michaelis-Menten
  - Cooperativity
- Feedback regulation
- Inhibition – types
  - Competitive
  - Non-competitive
  - Mixed (BC)
  - Uncompetitive (BC)
- Regulatory enzymes
  - Allosteric enzymes
  - Covalently-modified enzymes
  - Zymogen

## **Content Category 1B: *Transmission of genetic information from the gene to the protein***

Biomolecules and biomolecular assemblies interact in specific, highly-regulated ways to transfer sequence information between biopolymers in living organisms. By storing and transferring biological information, DNA and RNA enable living organisms to reproduce their complex components from one generation to the next. The nucleotide monomers of these biopolymers, being joined by phosphodiester linkages, form a polynucleotide molecule with a “backbone” composed of repeating sugar-phosphate units and “appendages” of nitrogenous bases. The unique sequence of bases in each gene provides specific information to the cell.

DNA molecules are composed of two polynucleotides that spiral around an imaginary axis, forming a double helix. The two polynucleotides are held together by hydrogen bonds between the paired bases and van der Waals interactions between the stacked bases. The pairing between the bases of two polynucleotides is very specific, and its complementarity allows for a precise replication of the DNA molecule.

The DNA inherited by an organism leads to specific traits by dictating the synthesis of the biomolecules (RNA molecules and proteins) involved in protein synthesis. While every cell in a multicellular organism inherits the same DNA, its expression is precisely regulated such that different genes are expressed by cells at different stages of development, by cells in different tissues, and by cells exposed to different stimuli.

The topics included in this Content Category concern not only the molecular mechanisms of the transmission of genetic information from the gene to the protein (*transcription* and *translation*), but also the biosynthesis of the important molecules and molecular assemblies that are involved in these mechanisms. The control of gene expression in prokaryotes and eukaryotes is also included.

Broadly speaking, the field of biotechnology uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use. The biotechnological techniques emphasized in this Content Category, however, are those that take advantage of the complementary structure of the double-stranded DNA molecule to synthesize, sequence, amplify, analyze, and identify polynucleotide sequences. Included within this treatment of biotechnology are those practical applications which directly impact humans, such as medical applications, human gene therapy, and pharmaceuticals.

Content in this category covers the biopolymers including ribonucleic acid (RNA), deoxyribonucleic acid (DNA), proteins, and the biochemical processes involved in carrying out the transfer of biological information from DNA. The topics and subtopics in this category are:

### **Nucleic Acid Structure and Function (BIO, OC, BC)**

- Description
- Nucleotides and nucleosides
  - Sugar phosphate backbone
  - Pyrimidine, purine residues
- Deoxyribonucleic acid (DNA): double helix, Watson–Crick model of DNA structure
- Base pairing specificity: A with T, G with C
- Function in transmission of genetic information (BIO)
- DNA denaturation, reannealing, hybridization

### **DNA Replication (BIO)**

- Mechanism of replication: separation of strands, specific coupling of free nucleic acids
- Semi-conservative nature of replication
- Specific enzymes involved in replication
- Origins of replication, multiple origins in eukaryotes
- Replicating the ends of DNA molecules

### **Repair of DNA (BIO)**

- Repair during replication
- Repair of mutations

### **Genetic Code (BIO)**

- Central Dogma: DNA → RNA → protein
- The triplet code
- Codon-anticodon relationship
- Degenerate code, wobble pairing
- Missense, nonsense codons
- Initiation, termination codons
- Messenger RNA (mRNA)

### **Transcription (BIO)**

- Transfer RNA (tRNA); ribosomal RNA (rRNA)
- Mechanism of transcription
- mRNA processing in eukaryotes, introns, exons
- Ribozymes, spliceosomes, small nuclear ribonucleoproteins (snRNPs), small nuclear RNA (snRNAs)
- Functional and evolutionary importance of introns

### **Translation (BIO)**

- Roles of mRNA, tRNA, rRNA
- Role and structure of ribosomes
- Initiation, termination co-factors
- Post-translational modification of proteins

### **Eukaryotic Chromosome Organization (BIO)**

- Chromosomal proteins
- Single copy vs. repetitive DNA
- Supercoiling
- Heterochromatin vs. euchromatin
- Telomeres, centromeres

### **Control of Gene Expression in Prokaryotes (BIO)**

- Operon Concept, Jacob-Monod Model
- Gene repression in bacteria
- Positive control in bacteria

### **Control of Gene Expression in Eukaryotes (BIO)**

- Transcriptional regulation
- DNA binding proteins, transcription factors
- Gene amplification and duplication
- Post-transcriptional control, basic concept of splicing (introns, exons)
- Cancer as a failure of normal cellular controls, oncogenes, tumor suppressor genes
- Regulation of chromatin structure
- DNA methylation
- Role of non-coding RNAs

### **Recombinant DNA and Biotechnology (BIO)**

- Gene cloning
- Restriction enzymes
- DNA libraries
- Generation of cDNA
- Hybridization
- Expressing cloned genes
- Polymerase Chain Reaction
- Gel Electrophoresis and Southern Blotting
- DNA sequencing
- Analyzing gene expression
- Determining gene function
- Stem cells
- Practical applications of DNA technology: medical applications, human gene therapy, pharmaceuticals, forensic evidence, environmental cleanup, agriculture
- Safety and ethics of DNA technology

## **Content Category 1C: *Transmission of heritable information from generation to generation and the processes that increase genetic diversity***

The information necessary to direct life functions is contained within discrete nucleotide sequences transmitted from generation to generation by mechanisms that, by nature of their various processes, provide the raw materials for evolution by increasing genetic diversity. Specific sequences of deoxyribonucleic acids store and transfer the heritable information necessary for the continuation of life from one generation to the next. These sequences, called *genes* — being part of longer DNA molecules — are organized, along with various proteins, into biomolecular assemblies called *chromosomes*.

Chromosomes pass from parents to offspring in sexually-reproducing organisms. The processes of *meiosis* and *fertilization* maintain a species' chromosome count during the sexual life cycle. Because parents pass on discrete heritable units that retain their separate identities in offspring, the laws of probability can be used to predict the outcome of some, but not all, genetic crosses.

The behavior of chromosomes during meiosis and fertilization is responsible for most of the genetic variation that arises each generation. Mechanisms that contribute to this genetic variation include independent assortment of chromosomes, crossing over, and random fertilization. Other mechanisms, such as mutation, random genetic drift, bottlenecks, and immigration, exist with the potential to affect the genetic diversity of individuals and populations. Collectively, the genetic diversity that results from these processes provides the raw material for evolution by natural selection.

The content in this category covers the mechanisms by which heritable information is transmitted from generation to generation, and the evolutionary processes that generate and act upon genetic variation. The topics and subtopics in this category are:

### **Evidence that DNA is Genetic Material (BIO)**

#### **Mendelian Concepts (BIO)**

- Phenotype and genotype
- Gene
- Locus
- Allele: single and multiple
- Homozygosity and heterozygosity
- Wild-type
- Recessiveness
- Complete dominance
- Co-dominance
- Incomplete dominance, leakage, penetrance, expressivity
- Hybridization: viability
- Gene pool

#### **Meiosis and Other Factors Affecting Genetic Variability (BIO)**

- Significance of meiosis
- Important differences between meiosis and mitosis
- Segregation of genes
  - Independent assortment
  - Linkage



- Recombination
  - Single crossovers
  - Double crossovers
  - Synaptonemal complex
  - Tetrad
- Sex-linked characteristics
- Very few genes on Y chromosome
- Sex determination
- Cytoplasmic/extranuclear inheritance
- Mutation
  - General concept of mutation — error in DNA sequence
  - Types of mutations: random, translation error, transcription error, base substitution, inversion, addition, deletion, translocation, mispairing
  - Advantageous vs. deleterious mutation
  - Inborn errors of metabolism
  - Relationship of mutagens to carcinogens
- Genetic drift
- Synapsis or crossing-over mechanism for increasing genetic diversity

### **Analytic Methods (BIO)**

- Hardy–Weinberg Principle
- Test cross
- Gene mapping: crossover frequencies
- Biometry: statistical methods

### **Evolution (BIO)**

- Natural selection
  - Fitness concept
  - Selection by differential reproduction
  - Concepts of natural and group selection
  - Evolutionary success as increase in percent representation in the gene pool of the next generation
- Speciation
  - Polymorphism
  - Adaptation and specialization
  - Inbreeding
  - Outbreeding
  - Bottlenecks
- Evolutionary time as measured by gradual random changes in genome

## Content Category 1D: *Principles of bioenergetics and fuel molecule metabolism*

Living things harness energy from fuel molecules in a controlled manner in order to sustain all of the processes responsible for maintaining life. Cell maintenance and growth is energetically costly. Cells harness the energy stored in fuel molecules, such as carbohydrates and fatty acids, and convert it into smaller units of chemical potential known as *adenosine triphosphate* (ATP).

The hydrolysis of ATP provides a ready source of energy for cells that can be coupled to other chemical processes in order to make them thermodynamically favorable. Fuel molecule mobilization, transport, and storage are regulated according to the needs of the organism.

The content in this category covers the principles of bioenergetics and fuel molecule catabolism. Details of oxidative phosphorylation including the role of chemiosmotic coupling and biological electron transfer reactions are covered, as are the general features of fatty acid and glucose metabolism. Additionally, regulation of these metabolic pathways, fuel molecule mobilization, transport, and storage are covered. The topics and subtopics in this category are:

### Principles of Bioenergetics (BC, GC)

- Bioenergetics/thermodynamics
  - Free energy/ $K_{eq}$ 
    - Equilibrium constant
    - Relationship of the equilibrium constant and  $\Delta G^\circ$
  - Concentration
    - Le Châtelier's Principle
  - Endothermic/exothermic reactions
  - Free energy:  $G$
  - Spontaneous reactions and  $\Delta G^\circ$
- Phosphoryl group transfers and ATP
  - ATP hydrolysis  $\Delta G \ll 0$
  - ATP group transfers
- Biological oxidation-reduction
  - Half-reactions
  - Soluble electron carriers
  - Flavoproteins

### Carbohydrates (BC, OC)

- Description
  - Nomenclature and classification, common names
  - Absolute configuration
  - Cyclic structure and conformations of hexoses
  - Epimers and anomers
- Hydrolysis of the glycoside linkage
- Monosaccharides
- Disaccharides
- Polysaccharides

### **Glycolysis, Gluconeogenesis, and the Pentose Phosphate Pathway (BIO, BC)**

- Glycolysis (aerobic), substrates and products
  - Feeder pathways: glycogen, starch metabolism
- Fermentation (anaerobic glycolysis)
- Gluconeogenesis (BC)
- Pentose phosphate pathway (BC)
- Net molecular and energetic results of respiration processes

### **Principles of Metabolic Regulation (BC)**

- Regulation of metabolic pathways (BIO, BC)
  - Maintenance of a dynamic steady state
- Regulation of glycolysis and gluconeogenesis
- Metabolism of glycogen
- Regulation of glycogen synthesis and breakdown
  - Allosteric and hormonal control
- Analysis of metabolic control

### **Citric Acid Cycle (BIO, BC)**

- Acetyl-CoA production (BC)
- Reactions of the cycle, substrates and products
- Regulation of the cycle
- Net molecular and energetic results of respiration processes

### **Metabolism of Fatty Acids and Proteins (BIO, BC)**

- Description of fatty acids (BC)
- Digestion, mobilization, and transport of fats
- Oxidation of fatty acids
  - Saturated fats
  - Unsaturated fats
- Ketone bodies (BC)
- Anabolism of fats (BIO)
- Non-template synthesis: biosynthesis of lipids and polysaccharides (BIO)
- Metabolism of proteins (BIO)

### **Oxidative Phosphorylation (BIO, BC)**

- Electron transport chain and oxidative phosphorylation, substrates and products, general features of the pathway
- Electron transfer in mitochondria
  - NADH, NADPH
  - Flavoproteins
  - Cytochromes
- ATP synthase, chemiosmotic coupling
  - Proton motive force
- Net molecular and energetic results of respiration processes
- Regulation of oxidative phosphorylation
- Mitochondria, apoptosis, oxidative stress (BC)

### **Hormonal Regulation and Integration of Metabolism (BC)**

- Higher level integration of hormone structure and function
- Tissue specific metabolism
- Hormonal regulation of fuel metabolism
- Obesity and regulation of body mass

## *Biological and Biochemical Foundations of Living Systems*

### **Foundational Concept 2<sup>10</sup>**

Highly-organized assemblies of molecules, cells, and organs interact to carry out the functions of living organisms.

Cells are the basic unit of structure in all living things. Mechanisms of cell division provide not only for the growth and maintenance of organisms, but also for the continuation of the species through asexual and sexual reproduction. The unique micro-environment to which a cell is exposed during development and division determines the fate of the cell by impacting gene expression and ultimately the cell's collection and distribution of macromolecules, and its arrangement of subcellular organelles.

In multicellular organisms, the processes necessary to maintain life are executed by groups of cells that are organized into specialized structures with specialized functions — both of which result from the unique properties of the cells' component molecules.

#### **Content Categories**

- *Category 2A* focuses on the assemblies of molecules, cells, and groups of cells within single cellular and multicellular organisms that function to execute the processes necessary to maintain life.
- *Category 2B* focuses on the structure, growth, physiology, and genetics of prokaryotes, and the structure and life cycles of viruses.
- *Category 2C* focuses on the processes of cell and nuclear division, and the mechanisms governing cell differentiation and specialization.

With these building blocks, medical students will be prepared to learn about the morphological and biochemical events that occur when somatic or germ cells divide, the mechanisms that regulate cell division and cell death, and the characteristics that distinguish normal from abnormal growth and development. These building blocks also prepare them to learn about the micro- and macroscopic structures of cells, tissues, and organs that lead to their unique and integrated functions, and how perturbations contribute to disease.

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<sup>10</sup> Foundational Concept 2 aligns with entering medical school competency 6 described by the Scientific Foundations for Future Physicians Committee.

## **Category 2A: Assemblies of molecules, cells, and groups of cells within single cellular and multicellular organisms**

The processes necessary to maintain life are executed by assemblies of molecules, cells, and groups of cells, all of which are organized into highly-specific structures as determined by the unique properties of their component molecules. The processes necessary to maintain life require that cells create and maintain internal environments within the cytoplasm and within certain organelles that are different from their external environments.

Cell membranes separate the internal environment of the cell from the external environment. The specialized structure of the membrane, as described in the fluid mosaic model, allows the cell to be selectively permeable and dynamic, with homeostasis maintained by the constant movement of molecules across the membranes through a combination of active and passive processes driven by several forces, including electrochemical gradients.

Eukaryotic cells also maintain internal membranes that partition the cell into specialized regions. These internal membranes facilitate cellular processes by minimizing conflicting interactions and increasing surface area where chemical reactions can occur. Membrane-bound organelles localize different processes or enzymatic reactions in time and space.

Through interactions between proteins bound to the membranes of adjacent cells, or between membrane-bound proteins and elements of the extracellular matrix, cells of multicellular organisms organize into tissues, organs, and organ systems. Certain membrane-associated proteins also play key roles in providing identification of tissues or recent events in the cell's history for purposes of recognition of "self" versus foreign molecules.

The content in this category covers the composition, structure, and function of cell membranes; the structure and function of the membrane-bound organelles of eukaryotic cells; and the structure and function of the major cytoskeletal elements. It covers the energetics of and mechanisms by which molecules, or groups of molecules, move across cell membranes. It also covers how cell–cell junctions and the extracellular matrix interact to form tissues with specialized functions. Epithelial tissue and connective tissue are covered in this category. The topics and subtopics in this category are:

### **Plasma Membrane (BIO, BC)**

- General function in cell containment
- Composition of membranes
  - Lipid components (BIO, BC, OC)
    - Phospholipids (and phosphatids)
    - Steroids
    - Waxes
  - Protein components
  - Fluid mosaic model
- Membrane dynamics
- Solute transport across membranes
  - Thermodynamic considerations
  - Osmosis
    - Colligative properties, osmotic pressure (GC)
  - Passive transport

- Active transport
  - Sodium/potassium pump
- Membrane channels
- Membrane potential
- Membrane receptors
- Exocytosis and endocytosis
- Intercellular junctions (BIO)
  - Gap junctions
  - Tight junctions
  - Desmosomes

### **Membrane-Bound Organelles and Defining Characteristics of Eukaryotic Cells (BIO)**

- Defining characteristics of eukaryotic cells: membrane bound nucleus, presence of organelles, mitotic division
- Nucleus
  - Compartmentalization, storage of genetic information
  - Nucleolus: location and function
  - Nuclear envelope, nuclear pores
- Mitochondria
  - Site of ATP production
  - Inner and outer membrane structure (BIO, BC)
  - Self-replication
- Lysosomes: membrane-bound vesicles containing hydrolytic enzymes
- Endoplasmic reticulum
  - Rough and smooth components
  - Rough endoplasmic reticulum site of ribosomes
  - Double membrane structure
  - Role in membrane biosynthesis
  - Role in biosynthesis of secreted proteins
- Golgi apparatus: general structure and role in packaging and secretion
- Peroxisomes: organelles that collect peroxides

### **Cytoskeleton (BIO)**

- General function in cell support and movement
- Microfilaments: composition and role in cleavage and contractility
- Microtubules: composition and role in support and transport
- Intermediate filaments, role in support
- Composition and function of cilia and flagella
- Centrioles, microtubule organizing centers

### **Tissues Formed From Eukaryotic Cells (BIO)**

- Epithelial cells
- Connective tissue cells

## **Content Category 2B: *The structure, growth, physiology, and genetics of prokaryotes and viruses***

The highly-organized assembly of molecules that is the cell represents the fundamental unit of structure, function, and organization in all living organisms. In the hierarchy of biological organization, the cell is the simplest collection of matter capable of carrying out the processes that distinguish living organisms. As such, cells have the ability to undergo metabolism; maintain homeostasis, including ionic gradients; the capacity to grow; move in response to their local environments; respond to stimuli; reproduce; and adapt to their environment in successive generations.

Life at cellular levels arises from structural order and its dynamic modulation. It does so in response to signals, thereby reflecting properties that result from individual and interactive features of molecular assemblies, their compartmentalization, and their interaction with environmental signals at many spatial and temporal scales.

The content in this category covers the classification, structure, growth, physiology, and genetics of prokaryotes, and the characteristics that distinguish them from eukaryotes. Viruses are also covered here. The topics and subtopics in this category are:

### **Cell Theory (BIO)**

- History and development
- Impact on biology

### **Classification and Structure of Prokaryotic Cells (BIO)**

- Prokaryotic domains
  - Archaea
  - Bacteria
- Major classifications of bacteria by shape
  - Bacilli (rod-shaped)
  - Spirilli (spiral shaped)
  - Cocci (spherical)
- Lack of nuclear membrane and mitotic apparatus
- Lack of typical eukaryotic organelles
- Presence of cell wall in bacteria
- Flagellar propulsion, mechanism

### **Growth and Physiology of Prokaryotic Cells (BIO)**

- Reproduction by fission
- High degree of genetic adaptability, acquisition of antibiotic resistance
- Exponential growth
- Existence of anaerobic and aerobic variants
- Parasitic and symbiotic
- Chemotaxis

### **Genetics of Prokaryotic Cells (BIO)**

- Existence of plasmids, extragenomic DNA
- Transformation: incorporation into bacterial genome of DNA fragments from external medium
- Conjugation



- Transposons (also present in eukaryotic cells)

### **Virus Structure (BIO)**

- General structural characteristics (nucleic acid and protein, enveloped and nonenveloped)
- Lack organelles and nucleus
- Structural aspects of typical bacteriophage
- Genomic content--RNA or DNA
- Size relative to bacteria and eukaryotic cells

### **Viral Life Cycle (BIO)**

- Self-replicating biological units that must reproduce within specific host cell
- Generalized phage and animal virus life cycles
  - Attachment to host, penetration of cell membrane or cell wall, and entry of viral genetic material
  - Use of host synthetic mechanism to replicate viral components
  - Self-assembly and release of new viral particles
- Transduction: transfer of genetic material by viruses
- Retrovirus life cycle: integration into host DNA, reverse transcriptase, HIV
- Prions and viroids: subviral particles

## **Content Category 2C: *Processes of cell division, differentiation, and specialization***

The ability of organisms to reproduce their own kind is the characteristic that best distinguishes living things. In sexually reproducing organisms, the continuity of life is based on the processes of cell division and meiosis.

The process of cell division is an integral part of the cell cycle. The progress of eukaryotic cells through the cell cycle is regulated by a complex molecular control system. Malfunctions in this system can result in unabated cellular division, and ultimately the development of cancer.

In the embryonic development of multicellular organisms, a fertilized egg gives rise to cells that differentiate into many different types of cells, each with a different structure, corresponding function, and location within the organism. During development, spatial–temporal gradients in the interactions between gene expression and various stimuli result in the structural and functional divergence of cells into specialized structure, organs, and tissues. The interaction of stimuli and genes is also explained by the progression of stem cells to terminal cells.

The content in this category covers the cell cycle; the causes, genetics, and basic properties of cancer; the processes of meiosis and gametogenesis; and the mechanisms governing cell specialization and differentiation. The topics and subtopics in this category are:

### **Mitosis (BIO)**

- Mitotic process: prophase, metaphase, anaphase, telophase, interphase
- Mitotic structures
  - Centrioles, asters, spindles
  - Chromatids, centromeres, kinetochores
  - Nuclear membrane breakdown and reorganization
  - Mechanisms of chromosome movement
- Phases of cell cycle: G<sub>0</sub>, G<sub>1</sub>, S, G<sub>2</sub>, M
- Growth arrest
- Control of cell cycle
- Loss of cell cycle controls in cancer cells

### **Biosignalling (BC)**

- Oncogenes, apoptosis

### **Reproductive System (BIO)**

- Gametogenesis by meiosis
- Ovum and sperm
  - Differences in formation
  - Differences in morphology
  - Relative contribution to next generation
- Reproductive sequence: fertilization, implantation, development, birth

### **Embryogenesis (BIO)**

- Stages of early development (order and general features of each)
  - Fertilization
  - Cleavage
  - Blastula formation

- Gastrulation
  - First cell movements
  - Formation of primary germ layers (endoderm, mesoderm, ectoderm)
- Neurulation
  - Major structures arising out of primary germ layers
  - Neural crest
  - Environment–gene interaction in development

### **Mechanisms of Development (BIO)**

- Cell specialization
  - Determination
  - Differentiation
  - Tissue types
- Cell–cell communication in development
- Cell migration
- Pluripotency: stem cells
- Gene regulation in development
- Programmed cell death
- Existence of regenerative capacity in various species
- Senescence and aging

## *Biological and Biochemical Foundations of Living Systems*

### **Foundational Concept 3<sup>11</sup>**

Complex systems of tissues and organs sense the internal and external environments of multicellular organisms, and through integrated functioning, maintain a stable internal environment within an ever-changing external environment.

As a result of the integration of a number of highly specialized organ systems, complex living things are able to maintain homeostasis while adapting to a constantly changing environment and participating in growth and reproduction. The interactions of these organ systems involves complex regulatory mechanisms that help maintain a dynamic and healthy equilibrium, regardless of their current state and environment.

#### **Content Categories**

- *Category 3A* focuses on the structure and functions of the nervous and endocrine systems, and the ways in which the systems work together to coordinate the responses of other body systems to both external and internal stimuli.
- *Category 3B* focuses on the structure and functions of the organ systems — circulatory, respiratory, digestive, immune, lymphatic, muscular, skeletal, and reproductive — and the ways these systems interact to fulfill their concerted roles in the maintenance and continuance of the living organism.

With these building blocks, medical students will be prepared to learn how the coordinated interactions of organ systems explain how the human body functions in health and in disease. They will also be prepared to learn how the principles of feedback control explain homeostatic and reproductive systems' maintenance of the internal environment, how perturbations in these systems may result in disease, and how homeostasis can be changed by disease.

<sup>11</sup> Foundational Concept 3 aligns with entering medical school competency 7 described by the Scientific Foundations for Future Physicians Committee.

### **Content Category 3A: *Structure and functions of the nervous and endocrine systems and ways in which these systems coordinate the organ systems***

The nervous and endocrine systems work together to detect external and internal signals, transmit and integrate information, and maintain homeostasis. They do all of this by producing appropriate responses to internal and external cues and stressors. The integration of these systems both with one another, and with the other organ systems, ultimately results in the successful and adaptive behaviors that allow for the propagation of the species.

Animals have evolved a nervous system that senses and processes internal and external information that is used to facilitate and enhance survival, growth, and reproduction. The nervous system interfaces with sensory and internal body systems to coordinate physiological and behavioral responses ranging from simple movements and small metabolic changes to long-distance migrations and social interactions. The physiological processes for nerve signal generation and propagation involve specialized membranes with associated proteins that respond to ligands and/or electrical field changes, signaling molecules and, by extension, the establishment and replenishment of ionic electrochemical gradients requiring ATP.

The endocrine system of animals has evolved to produce chemical signals that function internally to regulate stress responses, reproduction, development, energy metabolism, growth, and various individual and interactive behaviors. The integrated contributions of the nervous and endocrine systems to bodily functions are exemplified by the process whereby the signaling of neurons regulates hormone release, and by the targeting of membrane or nuclear receptors on neurons by circulating hormones.

The content in this category covers the structure, function, and basic aspects of nervous and endocrine systems, and their integration. The structure and function of nerve cells is also included in this category. The topics and subtopics in this category are:

#### **Nervous System: Structure and Function (BIO)**

- Major Functions
  - High level control and integration of body systems
  - Adaptive capability to external influences
- Organization of vertebrate nervous system
- Sensor and effector neurons
- Sympathetic and parasympathetic nervous systems: antagonistic control
- Reflexes
  - Feedback loop, reflex arc
  - Role of spinal cord and supraspinal circuits
- Integration with endocrine system: feedback control

#### **Nerve Cell (BIO)**

- Cell body: site of nucleus, organelles
- Dendrites: branched extensions of cell body
- Axon: structure and function
- Myelin sheath, Schwann cells, insulation of axon
- Nodes of Ranvier: propagation of nerve impulse along axon
- Synapse: site of impulse propagation between cells
- Synaptic activity: transmitter molecules
- Resting potential: electrochemical gradient

- Action potential
  - Threshold, all-or-none
  - Sodium/potassium pump
- Excitatory and inhibitory nerve fibers: summation, frequency of firing
- Glial cells, neuroglia

### **Electrochemistry (GC)**

- Concentration cell: direction of electron flow, Nernst equation

### **Biosignalling (BC)**

- Gated ion channels
  - Voltage gated
  - Ligand gated
- Receptor enzymes
- G protein-coupled receptors

### **Lipids (BC, OC)**

- Description; structure
  - Steroids
  - Terpenes and terpenoids

### **Endocrine System: Hormones and Their Sources (BIO)**

- Function of endocrine system: specific chemical control at cell, tissue, and organ level
- Definitions of endocrine gland, hormone
- Major endocrine glands: names, locations, products
- Major types of hormones
- Neuroendocrinology — relation between neurons and hormonal systems

### **Endocrine System: Mechanisms of Hormone Action (BIO)**

- Cellular mechanisms of hormone action
- Transport of hormones: blood supply
- Specificity of hormones: target tissue
- Integration with nervous system: feedback control regulation by second messengers

### **Category 3B: *Structure and integrative functions of the main organ systems***

Animals use a number of highly-organized and integrated organ systems to carry out the necessary functions associated with maintaining life processes. Within the body, no organ system is an island. Interactions and coordination between organ systems allow organisms to engage in the processes necessary to sustain life. For example, the organs and structures of the circulatory system carry out a number of functions, such as transporting:

- nutrients absorbed in the digestive system;
- gases absorbed from the respiratory system and muscle tissue;
- hormones secreted from the endocrine system; and
- blood cells produced in bone marrow to and from cells in the body to help fight disease.

The content in this category covers the structure and function of the major organ systems of the body including the respiratory, circulatory, lymphatic, immune, digestive, excretory, reproductive, muscle, skeletal, and skin systems. Also covered in this category is the integration of these systems and their control and coordination by the endocrine and nervous systems. The topics and subtopics in this category are:

#### **Respiratory System (BIO)**

- General function
  - Gas exchange, thermoregulation
  - Protection against disease: particulate matter
- Structure of lungs and alveoli
- Breathing mechanisms
  - Diaphragm, rib cage, differential pressure
  - Resiliency and surface tension effects
- Thermoregulation: nasal and tracheal capillary beds; evaporation, panting
- Particulate filtration: nasal hairs, mucus/cilia system in lungs
- Alveolar gas exchange
  - Diffusion, differential partial pressure
  - Henry's Law (GC)
- pH control
- Regulation by nervous control
  - CO<sub>2</sub> sensitivity

#### **Circulatory System (BIO)**

- Functions: circulation of oxygen, nutrients, hormones, ions and fluids, removal of metabolic waste
- Role in thermoregulation
- Four-chambered heart: structure and function
- Endothelial cells
- Systolic and diastolic pressure
- Pulmonary and systemic circulation
- Arterial and venous systems (arteries, arterioles, venules, veins)
  - Structural and functional differences

- Pressure and flow characteristics
- Capillary beds
  - Mechanisms of gas and solute exchange
  - Mechanism of heat exchange
  - Source of peripheral resistance
- Composition of blood
  - Plasma, chemicals, blood cells
  - Erythrocyte production and destruction; spleen, bone marrow
  - Regulation of plasma volume
- Coagulation, clotting mechanisms
- Oxygen transport by blood
  - Hemoglobin, hematocrit
  - Oxygen content
  - Oxygen affinity
  - Oxygen transport by blood; modification of oxygen affinity
- Carbon dioxide transport and level in blood
- Nervous and endocrine control

### **Lymphatic System (BIO)**

- Structure of lymphatic system
- Major functions
  - Equalization of fluid distribution
  - Transport of proteins and large glycerides
  - Production of lymphocytes involved in immune reactions
  - Return of materials to the blood

### **Immune System (BIO)**

- Innate (non-specific) vs. adaptive (specific) immunity
- Adaptive immune system cells
  - T-lymphocytes
  - B-lymphocytes
- Innate immune system cells
  - Macrophages
  - Phagocytes
- Concept of antigen and antibody
- Antigen presentation
- Clonal selection
- Antigen-antibody recognition
- Structure of antibody molecule
- Recognition of self vs. non-self, autoimmune diseases
- Major histocompatibility complex

### **Digestive System (BIO)**

- Ingestion
  - Saliva as lubrication and source of enzymes
  - Ingestion, esophagus, transport function



- Stomach
  - Storage and churning of food
  - Low pH, gastric juice, mucal protection against self-destruction
  - Production of digestive enzymes, site of digestion
  - Structure (gross)
- Liver
  - Structural relationship of liver within gastrointestinal system
  - Production of bile
  - Role in blood glucose regulation, detoxification
- Bile
  - Storage in gall bladder
  - Function
- Pancreas
  - Production of enzymes
  - Transport of enzymes to small intestine
- Small Intestine
  - Absorption of food molecules and water
  - Function and structure of villi
  - Production of enzymes, site of digestion
  - Neutralization of stomach acid
  - Structure (anatomic subdivisions)
- Large Intestine
  - Absorption of water
  - Bacterial flora
  - Structure (gross)
- Rectum: storage and elimination of waste, feces
- Muscular control
  - Peristalsis
- Endocrine control
  - Hormones
  - Target tissues
- Nervous control: the enteric nervous system

### **Excretory System (BIO)**

- Roles in homeostasis
  - Blood pressure
  - Osmoregulation
  - Acid-base balance
  - Removal of soluble nitrogenous waste
- Kidney structure
  - Cortex
  - Medulla
- Nephron structure
  - Glomerulus
  - Bowman's capsule
  - Proximal tubule

- Loop of Henle
- Distal tubule
- Collecting duct
- Formation of urine
  - Glomerular filtration
  - Secretion and reabsorption of solutes
  - Concentration of urine
  - Counter-current multiplier mechanism
- Storage and elimination: ureter, bladder, urethra
- Osmoregulation: capillary reabsorption of H<sub>2</sub>O, amino acids, glucose, ions
- Muscular control: sphincter muscle

### **Reproductive System (BIO)**

- Male and female reproductive structures and their functions
  - Gonads
  - Genitalia
  - Differences between male and female structures
- Hormonal control of reproduction
  - Male and female sexual development
  - Female reproductive cycle
  - Pregnancy, parturition, lactation
  - Integration with nervous control

### **Muscle System (BIO)**

- Important functions
  - Support: mobility
  - Peripheral circulatory assistance
  - Thermoregulation (shivering reflex)
- Structure of three basic muscle types: striated, smooth, cardiac
- Muscle structure and control of contraction
  - T-tubule system
  - Contractile apparatus
  - Sarcoplasmic reticulum
  - Fiber type
  - Contractile velocity of different muscle types
- Regulation of cardiac muscle contraction
- Oxygen debt: fatigue
- Nervous control
  - Motor neurons
  - Neuromuscular junction, motor end plates
  - Sympathetic and parasympathetic innervation
  - Voluntary and involuntary muscles

### **Specialized Cell - Muscle Cell (BIO)**

- Structural characteristics of striated, smooth, and cardiac muscle
- Abundant mitochondria in red muscle cells: ATP source

- Organization of contractile elements: actin and myosin filaments, crossbridges, sliding filament model
- Sarcomeres: “I” and “A” bands, “M” and “Z” lines, “H” zone
- Presence of troponin and tropomyosin
- Calcium regulation of contraction

### **Skeletal System (BIO)**

- Functions
  - Structural rigidity and support
  - Calcium storage
  - Physical protection
- Skeletal structure
  - Specialization of bone types, structures
  - Joint structures
  - Endoskeleton vs. exoskeleton
- Bone structure
  - Calcium/protein matrix
  - Cellular composition of bone
- Cartilage: structure and function
- Ligaments, tendons
- Endocrine control

### **Skin System (BIO)**

- Structure
  - Layer differentiation, cell types
  - Relative impermeability to water
- Functions in homeostasis and osmoregulation
- Functions in thermoregulation
  - Hair, erectile musculature
  - Fat layer for insulation
  - Sweat glands, location in dermis
  - Vasoconstriction and vasodilation in surface capillaries
- Physical protection
  - Nails, calluses, hair
  - Protection against abrasion, disease organisms
- Hormonal control: sweating, vasodilation, and vasoconstriction

## Distribution of Questions by Foundational Concept and Discipline

You may wonder how much chemistry you'll see on this section of the MCAT<sup>2015</sup> exam, or how many questions you'll get about a particular foundational concept. For each test form, you are likely to see questions distributed in the ways described below. These are the **approximate** percentages of questions you may see on a test form for each foundational concept and discipline<sup>12</sup>.

### Foundational Concept:

- 1: 50%
- 2: 25%
- 3: 25%

### Science Discipline:

- First-semester biochemistry : 25%
- Introductory biology: 65%
- General chemistry: 4%
- Organic chemistry: 6%

As we continue developing this test section, these percentages may be adjusted. Additional detail about any adjustments to this section will be posted on the MCAT<sup>2015</sup> website as soon as it is available.

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<sup>12</sup> You may also wonder how many questions you'll get about a particular Scientific Inquiry and Reasoning skill in the *Biological and Biochemical Foundations and Living Systems* section of the MCAT<sup>2015</sup> exam. This issue is currently under consideration by test development and content experts and will be shared with the public as soon as it is available.

## Sample Test Questions<sup>13</sup>: *Biological and Biochemical Foundations of Living Systems*

To give you an idea of what to expect from this section of the exam, sample test questions for the *Biological and Biochemical Foundations of Living Systems* section are provided below. The answer key appears below each question, along with the foundational concept, content category, and skill it targets.

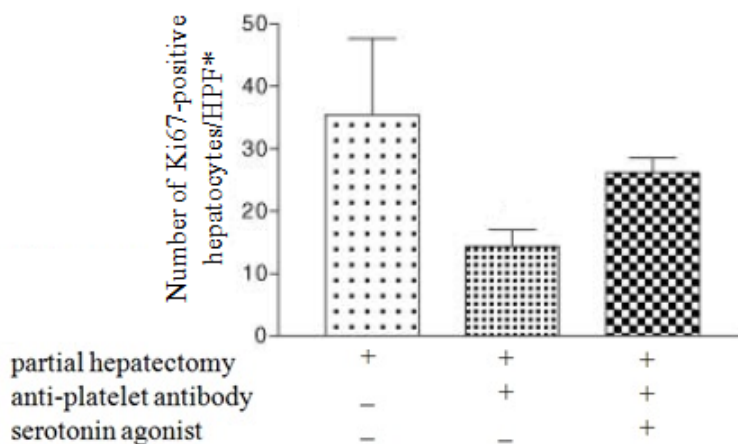
### Sample Passage 1: Questions 1–5

In many animals, including mice and humans, the liver quickly regenerates to its original size after a partial hepatectomy in which two-thirds of the organ is removed. Hepatocyte proliferation in response to this surgery is significantly reduced in mice with inadequate platelet activity or number.

Platelets carry 95% of blood serotonin, which is synthesized from tryptophan and secreted by endocrine cells in the lining of the gastrointestinal tract. Researchers experimentally tested the hypothesis that platelet serotonin is responsible for the platelets' positive effect on hepatocyte proliferation. The number of hepatocytes expressing the Ki67 protein, which is detected exclusively in the nuclei of proliferating cells, was used as a measure of liver regeneration.

#### Experiment 1

Wild-type mice were treated with an anti-platelet antibody that destroys 90% of their circulating platelets; a subset of these mice was also injected with a serotonin agonist, which mimics serotonin's actions on its receptors (Figure 1).

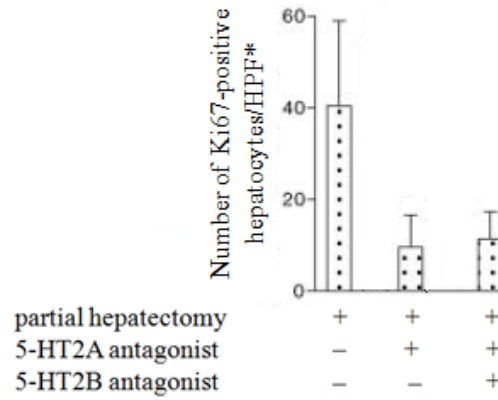


**Figure 1.** Effects of platelet depletion and serotonin agonist on hepatocyte proliferation (\*HPF = high power field)

<sup>13</sup> These sample passages and questions have not followed the same review and field-test procedures as do operational test materials.

### Experiment 2

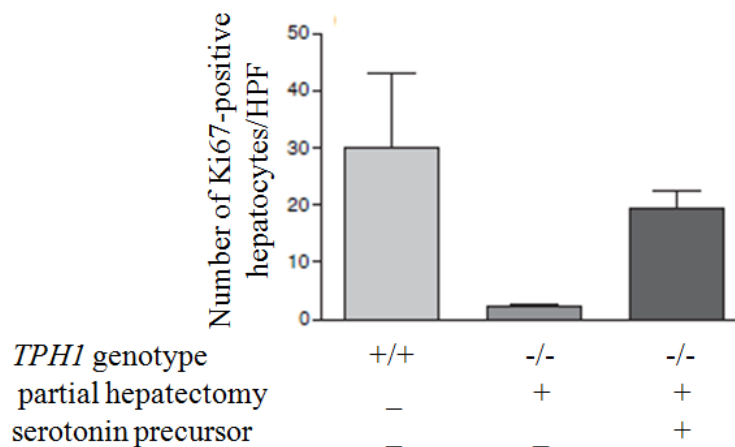
Wild-type mice were treated with antagonists of the serotonin receptors 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub>, receptors that are expressed on hepatocytes and other cells types (Figure 2).



**Figure 2.** Effects of serotonin receptor antagonists on hepatocyte proliferation

### Experiment 3

This experiment used *TPH1*<sup>-/-</sup> mice, which lack the gastrointestinal cell enzyme TPH1 necessary to make circulating serotonin; some of the *TPH1*<sup>-/-</sup> mice were injected with a serotonin biosynthetic precursor that could be converted into serotonin and then imported into platelets (Figure 3)



**Figure 3.** Effects of *TPH1*<sup>-/-</sup> genotype and serotonin precursor on hepatocyte proliferation

Source: Adapted from a paper by M. Lesurtel, *et al.*, ©2006 by the American Association for the Advancement of Science.

1) **The liver synthesizes factors that act cooperatively with platelets to facilitate which physiological process?**

- A. Cholesterol synthesis
- B. Glucose metabolism
- C. Blood clotting
- D. Fat digestion

Answer: C

Foundational Concept: 3

Content Category: 3B

Skill: 1

2) **According to the passage, platelets are LEAST likely to contain:**

- A. transmembrane serotonin transporters.
- B. ribosomes.
- C. serotonin.
- D. Ki67.

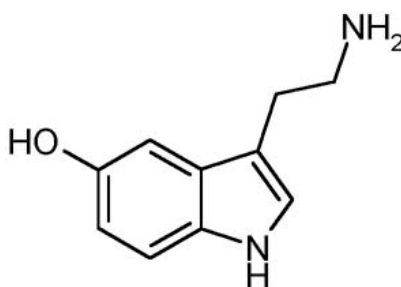
Answer: D

Foundational Concept: 3

Content Category: 3B

Skill: 2

3) **The structure of serotonin is shown.**



**Where are the serotonin receptors 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub> most likely to be located in hepatocytes?**

- A. In the nucleus
- B. In the cytosol
- C. Embedded in the mitochondrial membrane
- D. Embedded in the cell membrane

Answer: D

Foundational Concept: 2

Content Category: 2A

Skill: 2

- 4) Which finding, when combined with the data in the passage, is most likely to lead researchers to conclude that the 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub> receptor subtypes mediate serotonin-dependent liver regeneration?**
- A. Administration of 5-HT<sub>2A</sub> receptor agonist resulted in reduced Ki67 staining.
  - B. RNA for seven different receptor subtypes was detectible in naïve liver tissue.
  - C. Up-regulation of 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub> was observed during periods of peak hepatocyte proliferation.
  - D. Administration of 5-HT<sub>2C</sub> and 5-HT<sub>3</sub> receptor antagonists reduced the number of Ki67-positive cells.

Answer: C

Foundational Concept: 3

Content Category: 3B

Skill: 4

- 5) The amino acid precursor of serotonin is best described as having which type of R group?**
- A. Nonpolar, aliphatic
  - B. Polar, uncharged
  - C. Aromatic
  - D. Negatively charged

Answer: C

Foundational Concept: 1

Content Category: 1A

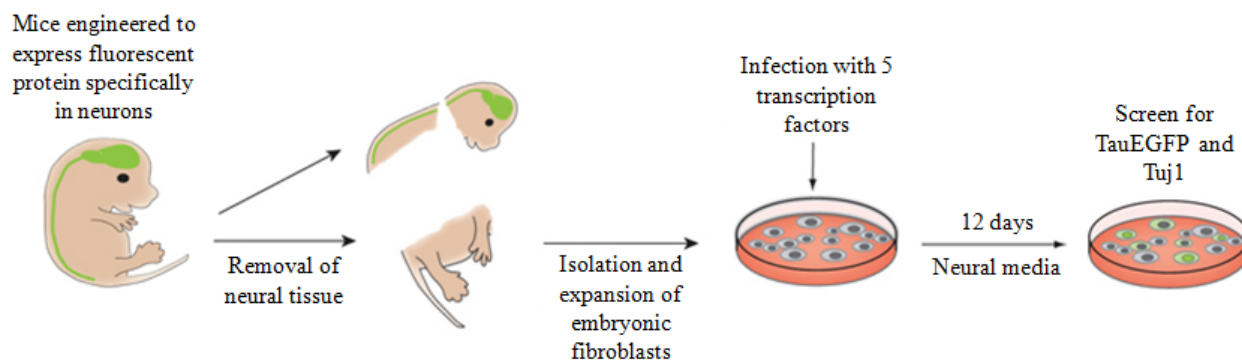
Skill: 1



## Sample Passage 2: Questions 6–10

Traditionally, cellular differentiation and lineage commitment are thought of as robust, irreversible developmental processes. Recently, however, it has been shown that fibroblasts can be reprogrammed to a pluripotent state with a combination of transcription factors. These results have caused scientists to question whether specific transcription factors could induce other defined somatic cell fates and not just an undifferentiated state.

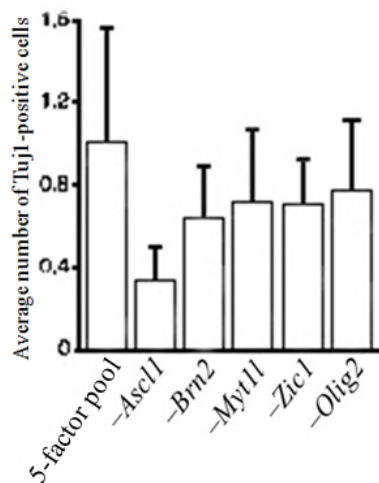
Scientists set out to test whether neural-lineage-specific transcription factors could convert embryonic fibroblasts from TauEGFP mice, mice engineered to express a green fluorescent protein in their neuronal tissues only, into neurons using the protocol shown in Figure 1.



**Figure 1.** Experimental protocol for infecting embryonic fibroblasts from engineered TauEGFP mice

Twelve days after infection, scientists observed the presence of cells that displayed bright green fluorescence and were positive for Tuj1, a neuron-specific class III  $\beta$ -tubulin. These cells also expressed several neuron-specific proteins including NeuN, which binds DNA. Tests revealed that while the majority of the fluorescent cells produced the excitatory neurotransmitter glutamate ( $\text{HOOC-CH}_2\text{-CH}_2\text{-CH(NH}_2\text{)-COOH}$ ), a few produced the inhibitory neurotransmitter  $\gamma$ -aminobutyric acid (GABA) ( $\text{HOOC-CH}_2\text{-CH}_2\text{-CH}_2\text{NH}_2$ ), much like neurons from the central nervous system.

In subsequent experiments, the scientists examined how each of the five transcription factors affected the production of Tuj1-positive cells by removing a single factor from the original 5-factor pool. The results are shown in Figure 2.



**Figure 2.** Average number of Tuj1-positive cells visible in a 20× field normalized to the 5-factor pool condition (– indicates omission of the specified gene; error bars = standard deviation)

Source: Adapted from: a paper by T. Vierbuchen, A. Ostermeier, Z. Pang, Y. Kokubu, T. Sudhof, and M. Wenig. ©2010 Macmillan Publishers, Ltd.

**6) Which type of enzyme catalyzes the conversion of glutamate to GABA?**

- A. Kinase
- B. Transferase
- C. Decarboxylase
- D. Dehydrogenase

Answer: C

Foundational Concept: 1

Content Category: 1A

Skill: 1

**7) What is the most likely reason why Tuj1 was used to assess the phenotype of cells that have incorporated the five candidate genes?**

- A. Tuj1 induces expression of the TauEGFP protein.
- B. Tuj1 is expressed in fibroblasts and neurons.
- C. Tuj1 is an early marker of neural differentiation.
- D. Tuj1 is present in embryonic and adult cells in culture.

Answer: C

Foundational Concept: 2

Content Category: 2C

Skill: 2

**8) Of the five candidate genes, which produces a factor that most markedly increases the efficiency with which fibroblasts commit to a neuronal lineage *in vitro*?**

- A. *Ascl1*
- B. *Brn2*
- C. *Zic1*
- D. *Olig2*

Answer: A

Foundational Concept: 1

Content Category: 1B

Skill: 4

**9) Does the experimental approach described in the passage yield cells that could be used in an animal model of Parkinson disease to replace dopamine-deficient neurons in the brain?**

- A. Yes, because the cells obtained have the functional characteristics of nerve cells
- B. Yes, because the cells obtained are similar to cells in the central nervous system
- C. No, because the cells obtained may contain tumorigenic pluripotent cells
- D. No, because the cells obtained lack the correct neurotransmitter phenotype

Answer: D

Foundational Concept: 3

Content Category: 3A

Skill: 2

**10) As one step in the estimation of the efficiency of neuronal induction, scientists calculated the average number of induced cells present in 30 randomly selected 20× visual fields. Which change to this particular aspect of the experimental protocol would increase the accuracy of the estimates of efficiency?**

- A. Increase the magnification of the oculars used to define the field of view.
- B. Increase the number of visual fields counted per petri dish.
- C. Select visual fields from the central portion of the petri dish where cell density is highest.
- D. Use the presence of green fluorescence to identify cells appropriate for quantification.

Answer: B

Foundational Concept: 2

Content Category: 2C

Skill: 3

**Sample Questions 11–14** (these questions are not associated with passages)

**11) Which type of molecule is LEAST likely to be found in a eukaryotic cell membrane?**

- A. Phospholipid
- B. Cholesterol
- C. Glycoprotein
- D. Peptidoglycan

Answer: D

Foundational Concept: 2

Content Category: 2A

Skill: 1

**12) An epitope is a region on the surface of an antigen molecule to which a specific antibody binds. The table shows the physical and biologic characteristics of several different molecules.**

Molecule	Molecular weight (daltons)	Number of epitopes
Diphtheria protein	72,000	8–12
Thyroglobulin	650,000	40
Serum albumin	66,000	6–8
Ribonuclease	14,000	3
Ovalbumin	45,000	5

**According to the information, which characteristics are most likely to be associated with a molecule's potential to elicit a strong immune response?**

- A. Higher molecular weight and increased number of epitopes
- B. Higher molecular weight and reduced number of epitopes
- C. Lower molecular weight and increased number of epitopes
- D. Lower molecular weight and reduced number of epitopes

Answer: A

Foundational Concept: 3

Content Category: 3B

Skill: 4

**13) Increasing the volume of air that reaches the alveoli and takes part in gas exchange will cause blood pH to:**

- A. increase, because the neural mechanisms that remove acid from the blood will be activated.
- B. increase, because the partial pressure of CO<sub>2</sub> in the blood will decrease.
- C. decrease, because the affinity of hemoglobin for oxygen will be increased.
- D. decrease, because the work associated with increased ventilation will consume more O<sub>2</sub>.

Answer: B

Foundational Concept: 3

Content Category: 3B

Skill: 2

**14) Scientists have hypothesized that mitochondria evolved from aerobic heterotrophic bacteria that entered and established symbiotic relationships with primitive eukaryotic anaerobes. According to this hypothesis, the bacteria that entered primitive eukaryotic cells were able to carry out which function(s) that the primitive eukaryotic cells could not?**

- A. Glycolysis
- B. Krebs cycle and electron transport
- C. Cell division
- D. Transcription and translation

Answer: B

Foundational Concept: 1

Content Category: 1D

Skill: 1

## Chapter 5: What will the *Chemical and Physical Foundations of Biological Systems* Section Test?

The *Chemical and Physical Foundations of Biological Systems* section asks you to solve problems by combining your knowledge of chemical and physical foundational concepts with your scientific inquiry and reasoning skills. This section tests your understanding of the mechanical, physical, and biochemical functions of human tissues, organs, and organ systems. It also tests your knowledge of the basic chemical and physical principles that underlie the mechanisms operating in the human body, and your ability to reason about and apply your understanding of these basic chemical and physical principles to living systems.

### Descriptions of Foundational Concepts and Content Categories

Following are detailed explanations of each foundational concept and related content category tested in this section. As with the *Biological and Biochemical Foundations of Living Systems* section, lists describing the specific topics and subtopics that define each content category for this section are provided. The same content list is provided to item writers who develop the content of the exam. Here is an excerpt from the content list.

#### **EXAMPLE**

#### **Separations and Purifications (OC, BC) ← Topic**

- Extraction: distribution of solute between two immiscible solvents ← Subtopic
- Distillation
- Chromatography
  - Basic principles involved in separation process
    - Column chromatography, gas-liquid chromatography
    - High pressure liquid chromatography
  - Paper chromatography
  - Thin-layer chromatography
- Separation and purification of peptides and proteins (BC)
  - Electrophoresis
  - Quantitative analysis
  - Chromatography
    - Size-exclusion
    - Ion-exchange
    - Affinity
- Racemic mixtures, separation of enantiomers (OC)

The abbreviations found in parentheses indicate the course(s) in which undergraduate students at many colleges and universities learn about the topics and associated subtopics. The course abbreviations are:

- BC = first semester of biochemistry
- BIO = two-semester sequence of introductory biology
- GC = two-semester sequence of general chemistry
- OC = two-semester sequence of organic chemistry

- PHY = two-semester sequence of introductory physics

In preparing for the MCAT<sup>2015</sup> exam, you will be responsible for learning the topics and associated subtopics at the levels at which they are taught in the courses listed in parentheses. A small number of subtopics have course abbreviations indicated in parentheses. In those cases, you are responsible only for learning the subtopics as they are taught in the course(s) indicated.

Using the excerpt above as an example:

- You are responsible for learning about the topic “Separations and Purifications” at the level at which it is taught in a typical two-semester organic chemistry sequence AND in a typical first-semester biochemistry course.
- You are responsible for learning about the subtopic “Separation and purifications of peptides and proteins” (and sub-subtopics) **only** at the level at which it is taught in a first-semester biochemistry course.
- You are responsible for learning about the subtopic “Racemic mixtures, separation of enantiomers” **only** at the level at which it is taught in a two-semester organic chemistry course.

Remember that course content at your school may differ from course content at other colleges and universities. The topics and subtopics that are described in this chapter may be covered in courses with different titles than those that are listed. Your pre-health advisor and faculty are important resources for questions about course content.



## *Chemical and Physical Foundations of Biological Systems*

### Foundational Concept 4<sup>14</sup>

Complex living organisms transport materials, sense their environment, process signals, and respond to changes using processes that can be understood in terms of physical principles.

The processes that take place within organisms follow the laws of physics. They can be quantified with equations that model the behavior at a fundamental level. For example, the principles of electromagnetic radiation, and its interactions with matter, can be exploited to generate structural information about molecules or to generate images of the human body. So, too, can atomic structure be used to predict the physical and chemical properties of atoms, including the amount of electromagnetic energy required to cause ionization.

#### Content Categories

- *Category 4A* focuses on motion, its causes, and various forms of energy and their interconversions.
- *Category 4B* focuses on the behavior of fluids, which is relevant to the functioning of the pulmonary and circulatory systems.
- *Category 4C* emphasizes the nature of electrical currents and voltages, how energy can be converted into electrical forms that can be used to perform chemical transformations or work, and how electrical impulses can be transmitted over long distances in the nervous system.
- *Category 4D* focuses on the properties of light and sound and how the interactions of light and sound with matter can be used by an organism to sense its environment, and how these interactions can also be used to generate structural information or images.
- *Category 4E* focuses on sub-atomic particles, the atomic nucleus, nuclear radiation, the structure of the atom, and how the configuration of any particular atom can be used to predict its physical and chemical properties.

With these building blocks, medical students will be able to apply their understanding of basic physical principles such as mass flow, transport, electricity, biomechanics, and signal detection and processing to the understanding of living systems and how perturbations from the normal functioning of specialized tissues contribute to disease.

#### Please Note

Topic lists in the *Preview Guide for MCAT<sup>2015</sup>* are preliminary. They will likely be refined (in minor ways) as testing experts continue working on the exam.

The MCAT<sup>2015</sup> website will be updated as information becomes available: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

<sup>14</sup> Foundational Concept 4 aligns with entering medical school competency 3 described by the Scientific Foundations for Future Physicians Committee.

## Content Category 4A: *Translational motion, forces, work, energy, and equilibrium in living systems*

The motion of any object can be described in terms of displacement, velocity, and acceleration. Objects accelerate when subjected to external forces and are at equilibrium when the net force and the net torque acting upon them are zero. Many aspects of motion can be calculated with the knowledge that energy is conserved, even though it may be converted into different forms. In a living system, the energy for motion comes from the metabolism of fuel molecules, but the energetic requirements remain subject to the same physical principles.

The content in this category covers several physics topics relevant to living systems including translational motion, forces, work, energy, and equilibrium. The topics and subtopics in this category are:

### Translational Motion (PHY)

- Units and dimensions
- Vectors, components
- Vector addition
- Speed, velocity (average and instantaneous)
- Acceleration

### Equilibrium (PHY)

- Concept of force, units
- Analysis of forces acting on an object
- Newton's First Law of Motion, inertia
- Torques, lever arms

### Work (PHY)

- Derived units, sign conventions
- Mechanical advantage
- Work Kinetic Energy Theorem
- $PV$  diagram: work done = area under or enclosed by curve

### Energy (PHY)

- Kinetic Energy:  $KE = \frac{1}{2} mv^2$ ; units
- Potential Energy
  - $PE = mgh$  (gravitational, local)
  - $PE = \frac{1}{2} kx^2$  (spring)
- Conservation of energy
- Conservative forces
- Power, units

#### Please Note

Topics that appear on multiple content lists will be treated differently. Questions will focus on the topics as they are described in the narrative for the content category.

## **Content Category 4B: Importance of fluids for the circulation of blood, gas movement, and gas exchange**

Fluids are featured in several physiologically important processes, including the circulation of blood, gas movement into and out of the lungs, and gas exchange with the blood. The energetic requirements of fluid dynamics can be modeled using physical equations. A thorough understanding of fluids is necessary to understand the origins of numerous forms of disease.

The content in this category covers hydrostatic pressure, fluid flow rates, viscosity, the Kinetic Molecular Theory of Gases, and the Ideal Gas Law. The topics and subtopics in this category are:

### **Fluids (PHY)**

- Density, specific gravity
- Buoyancy, Archimedes' Principle
- Hydrostatic pressure
  - Pascal's Law
  - Hydrostatic pressure;  $P = \rho gh$  (pressure versus depth)
- Viscosity: Poiseuille Flow
- Continuity equation ( $A \cdot v = \text{constant}$ )
- Concept of turbulence at high velocities
- Surface tension
- Bernoulli's equation
- Venturi effect, pitot tube

### **Circulatory System (BIO)**

- Arterial and venous systems; pressure and flow characteristics

### **Gas Phase (GC, PHY)**

- Absolute temperature, (K) Kelvin Scale
- Pressure, simple mercury barometer
- Molar volume at 0°C and 1 atm = 22.4 L/mol
- Ideal gas
  - Definition
  - Ideal Gas Law:  $PV = nRT$
  - Boyle's Law:  $PV = \text{constant}$
  - Charles' Law:  $V/T = \text{constant}$
  - Avogadro's Law:  $V/n = \text{constant}$
- Kinetic Molecular Theory of Gases
  - Heat capacity at constant volume and at constant pressure (PHY)
  - Boltzmann's Constant (PHY)
- Deviation of real gas behavior from Ideal Gas Law
  - Qualitative
  - Quantitative (Van der Waals' Equation)
- Partial pressure, mole fraction
- Dalton's Law relating partial pressure to composition

## **Content Category 4C: *Electrochemistry and electrical circuits and their elements***

Charged particles can be set in motion by the action of an applied electrical field, and can be used to transmit energy or information over long distances. The energy released during certain chemical reactions can be converted to electrical energy, which can be harnessed to perform other reactions or work.

Physiologically, a concentration gradient of charged particles is set up across the cell membrane of neurons at considerable energetic expense. This allows for the rapid transmission of signals using electrical impulses — changes in the electrical voltage across the membrane — under the action of some external stimulus.

The content in this category covers electrical circuit elements, electrical circuits, and electrochemistry. The topics and subtopics in this category are:

### **Electrostatics (PHY)**

- Charge, conductors, charge conservation
- Insulators
- Electric field **E**
  - Field lines
  - Field due to charge distribution
- Potential difference, absolute potential at point in space

### **Circuit Elements (PHY)**

- Current  $I = \Delta Q / \Delta t$ , sign conventions, units
- Electromotive force, voltage
- Resistance
  - Ohm's Law:  $I = V/R$
  - Resistors in series
  - Resistors in parallel
  - Resistivity:  $\rho = R \cdot A/L$
- Capacitance
  - Parallel plate capacitor
  - Energy of charged capacitor
  - Capacitors in series
  - Capacitors in parallel
  - Dielectrics
- Conductivity
  - Metallic
  - Electrolytic
- Meters

### **Electrochemistry (GC)**

- Electrolytic cell
  - Electrolysis
  - Anode, cathode
  - Electrolyte

- Faraday's Law relating amount of elements deposited (or gas liberated) at an electrode to current
- Electron flow, oxidation, and reduction at the electrodes
- Galvanic or Voltaic cells
  - Half-reactions
  - Reduction potentials, cell potential
  - Direction of electron flow
- Concentration cell
- Batteries
  - Electromotive force, Voltage
  - Lead-storage batteries
  - Nickel-cadmium batteries

**Specialized Cell – Nerve Cell (BIO)**

- Myelin sheath, Schwann cells, insulation of axon
- Nodes of Ranvier: propagation of nerve impulse along axon

### **Content Category 4D: *How light and sound interact with matter***

Light is a form of electromagnetic radiation — waves of electric and magnetic fields that transmit energy. The behavior of light depends on its frequency (or wavelength). The properties of light are exploited in the optical elements of the eye to focus rays of light on sensory elements. When light interacts with matter, spectroscopic changes occur that can be used to identify the material on an atomic or molecular level. Differential absorption of electromagnetic radiation can be used to generate images useful in diagnostic medicine. Interference and diffraction of light waves are used in many analytical and diagnostic techniques. The photon model of light explains why electromagnetic radiation of different wavelengths interacts differently with matter.

When mechanical energy is transmitted through solids, liquids, and gases, oscillating pressure waves known as “sound” are generated. Sound waves are audible if the sensory elements of the ear vibrate in response to exposure to these vibrations. The detection of reflected sound waves is utilized in ultrasound imaging. This non-invasive technique readily locates dense subcutaneous structures, such as bone and cartilage, and is very useful in diagnostic medicine.

The content in this category covers the properties of both light and sound and how these energy waves interact with matter. The topics and subtopics in this category are:

#### **Sound (PHY)**

- Production of sound
- Relative speed of sound in solids, liquids, and gases
- Intensity of sound, decibel units, log scale
- Attenuation (Damping)
- Doppler Effect: moving sound source or observer, reflection of sound from a moving object
- Pitch
- Resonance in pipes and strings
- Ultrasound
- Shock waves

#### **Light, Electromagnetic Radiation (PHY)**

- Concept of Interference; Young Double-slit Experiment
- Thin films, diffraction grating, single-slit diffraction
- Other diffraction phenomena, X-ray diffraction
- Polarization of light
- Circular polarization
- Properties of electromagnetic radiation
  - Velocity equals constant  $c$ , *in vacuo*
  - Electromagnetic radiation consists of perpendicularly oscillating electric and magnetic fields; direction of propagation is perpendicular to both
- Classification of electromagnetic spectrum, photon energy  $E = (hf)$
- Visual spectrum, color

### Molecular Structure and Absorption Spectra (OC)

- Infrared region
  - Intramolecular vibrations and rotations
  - Recognizing common characteristic group absorptions, fingerprint region
- Visible region (GC)
  - Absorption in visible region gives complementary color (e.g., carotene)
  - Effect of structural changes on absorption (e.g., indicators)
- Ultraviolet region
  - $\pi$ -electron and non-bonding electron transitions
  - Conjugated systems
- NMR spectroscopy
  - Protons in a magnetic field; equivalent protons
  - Spin-spin splitting

### Geometrical Optics (PHY)

- Reflection from plane surface: angle of incidence equals angle of reflection
- Refraction, refractive index  $n$ , Snell's law:  $n_1 \sin \theta_1 = n_2 \sin \theta_2$
- Dispersion, change of index of refraction with wavelength
- Conditions for total internal reflection
- Spherical mirrors
  - Center of curvature
  - Focal length
  - Real and virtual images
- Thin lenses
  - Converging and diverging lenses
  - Use of formula  $1/p + 1/q = 1/f$ , with sign conventions
  - Lens strength, diopters
- Combination of lenses
- Lens aberration
- Optical Instruments, including the human eye

## **Content Category 4E: Atoms, nuclear decay, electronic structure, and atomic chemical behavior**

Atoms are classified by their *atomic number*: the number of protons in the atomic nucleus, which also includes neutrons. Chemical interactions between atoms are the result of electrostatic forces involving the electrons and the nuclei. Because neutrons are uncharged they do not dramatically affect the chemistry of any particular type of atom, but do affect the stability of the nucleus itself.

When a nucleus is unstable, decay results from one of several different processes, which are random, but occur at well-characterized average rates. The products of nuclear decay (alpha, beta, and gamma rays) can interact with living tissue, breaking chemical bonds and ionizing atoms and molecules in the process.

The electronic structure of an atom is responsible for its chemical and physical properties. Only discrete energy levels are allowed for electrons. These levels are described individually by quantum numbers. Since the outermost, or *valence*, electrons are responsible for the strongest chemical interactions, a description of these electrons alone is a good first approximation to describe the behavior any particular type of atom.

Mass spectrometry is an analytical tool that allows characterization of atoms or molecules, based on well recognized fragmentation patterns and the charge to mass ratio ( $m/z$ ) of ions generated in the gas phase.

The content in this category covers atomic structure, nuclear decay, electronic structure, and the periodic nature of atomic chemical behavior. The topics and subtopics in this category are:

### **Atomic Nucleus (PHY, GC)**

- Atomic number, atomic weight
- Neutrons, protons, isotopes
- Nuclear forces, binding energy
- Radioactive decay
  - $\alpha$ ,  $\beta$ ,  $\gamma$  decay
  - Half-life, exponential decay, semi-log plots
- Mass spectrometer

### **Electronic Structure (PHY, GC)**

- Orbital structure of hydrogen atom, principal quantum number  $n$ , number of electrons per orbital (GC)
- Ground state, excited states
- Absorption and emission line spectra
- Use of Pauli Exclusion Principle
- Paramagnetism and diamagnetism
- Conventional notation for electronic structure (GC)
- Bohr atom
- Heisenberg Uncertainty Principle
- Effective nuclear charge (GC)
- Photoelectric effect



### The Periodic Table – Classification of Elements into Groups by Electronic Structure (GC)

- Alkali metals
- Alkaline earth metals: their chemical characteristics
- Halogens: their chemical characteristics
- Noble gases: their physical and chemical characteristics
- Transition metals
- Representative elements
- Metals and non-metals
- Oxygen group

### The Periodic Table – Variations of Chemical Properties with Group and Row (GC)

- Valence electrons
- First and second ionization energy
  - Definition
  - Prediction from electronic structure for elements in different groups or rows
- Electron affinity
  - Definition
  - Variation with group and row
- Electronegativity
  - Definition
  - Comparative values for some representative elements and important groups
- Electron shells and the sizes of atoms
- Electron shells and the sizes of ions

### Stoichiometry (GC)

- Molecular weight
- Empirical versus molecular formula
- Metric units commonly used in the context of chemistry
- Description of composition by percent mass
- Mole concept, Avogadro's number  $N_A$
- Definition of density
- Oxidation number
  - Common oxidizing and reducing agents
  - Disproportionation reactions
- Description of reactions by chemical equations
  - Conventions for writing chemical equations
  - Balancing equations, including redox equations
  - Limiting reactants
  - Theoretical yields

## *Chemical and Physical Foundations of Biological Systems*

### **Foundational Concept 5<sup>15</sup>**

The principles that govern chemical interactions and reactions form the basis for a broader understanding of the molecular dynamics of living systems.

The chemical processes that take place within organisms are readily understood within the framework of the behavior of solutions, thermodynamics, molecular structure, intermolecular interactions, molecular dynamics, and molecular reactivity.

#### **Content Categories**

- *Category 5A* emphasizes the nature of solution formation, factors that affect solubility, and the properties and behavior of aqueous solutions, with special emphasis on the acid-base behavior of dissolved solutes.
- *Category 5B* focuses on molecular structure and how it affects the strength of intermolecular interactions.
- *Category 5C* emphasizes how differential intermolecular interactions can be used to effect chemical separations.
- *Category 5D* emphasizes the varied nature of biologically-relevant molecules, and how patterns of covalent bonding can be used to predict the chemical reactivity of these molecules and their structure and function within a living system.
- *Category 5E* emphasizes how relative energy dictates the overall favorability of chemical processes and the rate at which these processes can occur.

With these building blocks, medical students will be able to apply the understanding of basic chemical principles to an understanding of living systems, and will be prepared to learn how the atomic and molecular characteristics of biological constituents can be used to predict normal and pathological molecular function.

<sup>15</sup> Foundational Concept 5 aligns with entering medical school competency 4 described by the Scientific Foundations for Future Physicians Committee.

## Content Category 5A: *Unique nature of water and its solutions*

In order to fully understand the complex and dynamic nature of living systems, it is first necessary to understand the unique nature of water and its solutions. The unique properties of water allow it to strongly interact with and mobilize many types of solutes, including ions. Water is also unique in its ability to absorb energy and buffer living systems from the chemical changes necessary to sustain life.

The content in this category covers the nature of solutions, solubility, acids, bases, and buffers. The topics and subtopics in this category are:

### Acid/Base Equilibria (GC, BC)

- Bronsted-Lowry definition of acid, base
- Ionization of water
  - $K_w$ , its approximate value ( $K_w = [\text{H}^+][\text{OH}^-] = 10^{-14}$  at 25°C, 1 atm)
  - Definition of pH: pH of pure water
- Conjugate acids and bases (e.g.,  $\text{NH}_4^+$  and  $\text{NH}_3$ )
- Strong acids and bases (e.g., nitric, sulfuric)
- Weak acids and bases (e.g., acetic, benzoic)
  - Dissociation of weak acids and bases with or without added salt
  - Hydrolysis of salts of weak acids or bases
  - Calculation of pH of solutions of salts of weak acids or bases
- Equilibrium constants  $K_a$  and  $K_b$ :  $\text{p}K_a$ ,  $\text{p}K_b$
- Buffers
  - Definition and concepts (common buffer systems)
  - Influence on titration curves

### Ions in Solutions (GC, BC)

- Anion, cation: common names, formulas and charges for familiar ions (e.g.,  $\text{NH}_4^+$  ammonium,  $\text{PO}_4^{3-}$  phosphate,  $\text{SO}_4^{2-}$  sulfate)
- Hydration, the hydronium ion

### Solubility (GC)

- Units of concentration (e.g., molarity)
- Solubility product constant; the equilibrium expression  $K_{sp}$
- Common-ion effect, its use in laboratory separations
  - Complex ion formation
  - Complex ions and solubility
  - Solubility and pH

### Titration (GC)

- Indicators
- Neutralization
- Interpretation of the titration curves
- Redox titration

## Content Category 5B: *Nature of molecules and intermolecular interactions*

Covalent bonding involves the sharing of electrons between atoms. If the result of such interactions is not a network solid, then the covalently bonded substance will be discrete and molecular.

The shape of molecules can be predicted based on electrostatic principles and quantum mechanics since only two electrons can occupy the same orbital. Bond polarity (both direction and magnitude) can be predicted based on knowledge of the valence electron structure of the constituent atoms. The strength of intermolecular interactions depends on molecular shape and the polarity of the covalent bonds present. The solubility and other physical properties of molecular substances depend on the strength of intermolecular interactions.

The content in this category covers the nature of molecules and includes covalent bonding, molecular structure, nomenclature, and intermolecular interactions. The topics and subtopics in this category are:

### Covalent Bond (GC)

- Lewis Electron Dot formulas
  - Resonance structures
  - Formal charge
  - Lewis acids and bases
- Partial ionic character
  - Role of electronegativity in determining charge distribution
  - Dipole Moment
- $\sigma$  and  $\pi$  bonds
  - Hybrid orbitals:  $sp^3$ ,  $sp^2$ ,  $sp$  and respective geometries
  - Valence shell electron pair repulsion and the prediction of shapes of molecules (e.g.,  $\text{NH}_3$ ,  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ )
  - Structural formulas for molecules involving H, C, N, O, F, S, P, Si, Cl
  - Delocalized electrons and resonance in ions and molecules
- Multiple bonding
  - Affect on bond length and bond energies
  - Rigidity in molecular structure
- Stereochemistry of covalently bonded molecules (OC)
  - Isomers
    - Structural isomers
    - Stereoisomers (e.g., diastereomers, enantiomers, cis/trans isomers)
    - Conformational isomers
  - Polarization of light, specific rotation
  - Absolute and relative configuration
    - Conventions for writing *R* and *S* forms
    - Conventions for writing *E* and *Z* forms

### Liquid Phase – Intermolecular Forces (GC)

- Hydrogen bonding
- Dipole Interactions
- Van der Waals' Forces (London dispersion forces)

### **Content Category 5C: *Separation and purification methods***

Analysis of complex mixtures of substances — especially biologically relevant materials — typically requires separation of the components. Many methods have been developed to accomplish this task, and the method used is dependent on the types of substances which comprise the mixture. All of these methods rely on the magnification of potential differences in the strength of intermolecular interactions.

The content in this category covers separation and purification methods including: extraction, liquid and gas chromatography, and electrophoresis. The topics and subtopics in this category are:

#### **Separations and Purifications (OC, BC)**

- Extraction: distribution of solute between two immiscible solvents
- Distillation
- Chromatography
  - Basic principles involved in separation process
    - Column chromatography, gas-liquid chromatography
    - High pressure liquid chromatography
  - Paper chromatography
  - Thin-layer chromatography
- Separation and purification of peptides and proteins (BC)
  - Electrophoresis
  - Quantitative analysis
  - Chromatography
    - Size-exclusion
    - Ion-exchange
    - Affinity
- Racemic mixtures, separation of enantiomers (OC)

## **Content Category 5D: *Structure, function, and reactivity of biologically-relevant molecules***

The structure of biological molecules forms the basis of their chemical reactions including oligomerization and polymerization. Unique aspects of each type of biological molecule dictate their role in living systems, whether providing structure or information storage, or serving as fuel and catalysts.

The content in this category covers the structure, function, and reactivity of biologically-relevant molecules including the mechanistic considerations that dictate their modes of reactivity. The topics and subtopics in this category are:

### **Nucleotides and Nucleic Acids (OC, BC, BIO)**

- Nucleotides and nucleosides: composition
  - Sugar phosphate backbone
  - Pyrimidine, purine residues
- Deoxyribonucleic acid: DNA, double helix
- Chemistry (OC, BC)
- Other functions (OC, BC)

### **Amino Acids, Peptides, Proteins (OC, BC)**

- Amino acids: description
  - Absolute configuration at the  $\alpha$  position
  - Dipolar ions
  - Classification
    - Acidic or basic
    - Hydrophilic or hydrophobic
  - Synthesis of  $\alpha$ -amino acids (OC)
    - Strecker Synthesis
    - Gabriel Synthesis
- Peptides and proteins: reactions
  - Sulfur linkage for cysteine and cystine
  - Peptide linkage: polypeptides and proteins
  - Hydrolysis
- General Principles
  - 1° structure of proteins
  - 2° structure of proteins
  - 3° structure of proteins
  - Isoelectric point

### **The Three-Dimensional Protein Structure (BC)**

- Conformational stability
  - Hydrophobic interactions
  - Solvation layer (entropy)
- 4° quaternary structure
- Denaturing and Folding

### Non-Enzymatic Protein Function (BC)

- Binding
- Immune system
- Motor

### Lipids (BC, OC)

- Types
  - Storage
    - Triacyl glycerols
    - Free fatty acids: saponification
  - Structural
    - Phospholipids and phosphatids
    - Sphingolipids
    - Waxes
  - Signals/cofactors
    - Fat-soluble vitamins
    - Steroids
    - Prostaglandins

### Carbohydrates (OC)

- Description
  - Nomenclature and classification, common names
  - Absolute configuration
  - Cyclic structure and conformations of hexoses
  - Epimers and anomers
- Hydrolysis of the glycoside linkage
- Keto-enol tautomerism of monosaccharides
- Disaccharides (BC)
- Polysaccharides (BC)

### Aldehydes and Ketones (OC)

- Description
  - Nomenclature
  - Physical properties
- Important reactions
  - Nucleophilic addition reactions at C=O bond
    - Acetal, hemiacetal
    - Imine, enamine
    - Hydride reagents
    - Cyanohydrin
  - Oxidation of aldehydes
  - Reactions at adjacent positions: enolate chemistry
    - Keto-enol tautomerism ( $\alpha$ -racemization)
    - Aldol condensation, retro-aldol
    - Kinetic versus thermodynamic enolate
- General principles

- Effect of substituents on reactivity of C=O; steric hindrance
- Acidity of  $\alpha$ -H; carbanions

### Alcohols (OC)

- Description
  - Nomenclature
  - Physical properties (acidity, hydrogen bonding)
- Important reactions
  - Oxidation
  - Protection of alcohols
  - Preparation of mesylates and tosylates

### Carboxylic Acids (OC)

- Description
  - Nomenclature
  - Physical properties
- Important reactions
  - Carboxyl group reactions
    - Amides (and lactam), esters (and lactone), anhydride formation
    - Reduction
    - Decarboxylation
    - Reactions at 2-position, substitution

### Acid Derivatives (Anhydrides, Amides, Esters) (OC)

- Description
  - Nomenclature
  - Physical properties
- Important reactions
  - Nucleophilic substitution
  - Transesterification
  - Hydrolysis of amides
- General principles
  - Relative reactivity of acid derivatives
  - Steric effects
  - Electronic effects
  - Strain (e.g.,  $\beta$ -lactams)

### Phenols (OC, BC)

- Oxidation and reduction (e.g., hydroquinones), ubiquinones: biological  $2e^-$  redox centers

### Polycyclic and Heterocyclic Aromatic Compounds (OC, BC)

- Biological aromatic heterocycles



## Content Category 5E: *Principles of chemical thermodynamics and kinetics*

The processes that occur in living systems are dynamic, and they follow the principles of chemical thermodynamics and kinetics. The position of chemical equilibrium is dictated by the relative energies of products and reactants. The rate at which chemical equilibrium is attained is dictated by a variety of factors: concentration of reactants, temperature, and the amount of catalyst (if any).

Biological systems have evolved to harness energy, and utilize it in very efficient ways to support all processes of life, including homeostasis and anabolism. Biological catalysts, known as *enzymes*, have evolved to allow all of the relevant chemical reactions required to sustain life to occur both rapidly and efficiently, and under the narrow set of conditions required.

The content in this category covers all principles of chemical thermodynamics and kinetics including enzymatic catalysis. The topics and subtopics in this category are:

### Enzymes (BC, BIO)

- Classification by reaction type
- Mechanism
  - Substrates and enzyme specificity
  - Active site model
  - Induced-fit model
  - Cofactors, coenzymes and vitamins
- Kinetics
  - General (catalysis)
  - Michaelis-Menten
  - Cooperativity
  - Effects of local conditions on enzyme activity
- Inhibition
- Regulatory enzymes
  - Allosteric
  - Covalently modified

### Principles of Bioenergetics (BC)

- Bioenergetics/thermodynamics
  - Free energy/ $K_{eq}$
  - Concentration
- Phosphorylation/ATP
  - ATP hydrolysis  $\Delta G \ll 0$
  - ATP group transfers
- Biological oxidation–reduction
  - Half-reactions
  - Soluble electron carriers
  - Flavoproteins

### Phosphorus Compounds (OC)

- Description, structure of phosphoric acids

### Energy Changes in Chemical Reactions – Thermochemistry, Thermodynamics (GC, PHY)

- Thermodynamic system – state function
- Zeroth Law – concept of temperature
- First Law:  $\Delta E = Q - W$  (conservation of energy)
- Second Law – concept of entropy
  - Entropy as a measure of “disorder”
  - Relative entropy for gas, liquid, and crystal states
- Measurement of heat changes (calorimetry), heat capacity, specific heat
- Heat transfer – conduction, convection, radiation (PHY)
- Endothermic/exothermic reactions (GC)
  - Enthalpy,  $H$ , and standard heats of reaction and formation
  - Hess’ Law of Heat Summation
- Bond dissociation energy as related to heats of formation (GC)
- Free energy:  $G$  (GC)
- Spontaneous reactions and  $\Delta G^\circ$  (GC)
- Coefficient of expansion (PHY)
- Heat of fusion, heat of vaporization
- Phase diagram: pressure and temperature

### Rate Processes in Chemical Reactions – Kinetics and Equilibrium (GC)

- Reaction rate
- Dependence of reaction rate upon concentration of reactants
  - Rate law, rate constant
  - Reaction order
- Rate-determining step
- Dependence of reaction rate upon temperature
  - Activation energy
    - Activated complex or transition state
    - Interpretation of energy profiles showing energies of reactants, products, activation energy, and  $\Delta H$  for the reaction
  - Use of the Arrhenius Equation
- Kinetic control versus thermodynamic control of a reaction
- Catalysts
- Equilibrium in reversible chemical reactions
  - Law of Mass Action
  - Equilibrium Constant
  - Application of Le Châtelier’s Principle
- Relationship of the equilibrium constant and  $\Delta G^\circ$

## Distribution of Questions by Foundational Concept and Discipline

You may wonder how much chemistry you'll see on this section of the MCAT<sup>2015</sup> exam, or how many questions you'll get about a particular foundational concept. For each test form, you are likely to see questions distributed in the ways that are described below. These are the **approximate** percentages of questions you may see on a test form for each foundational concept and discipline<sup>16</sup>.

### Foundational Concept:

- 4: 40%
- 5: 60%

### Science Discipline:

- First-semester biochemistry: 25%
- Introductory biology: 2%
- General chemistry: 33%
- Organic chemistry: 15%
- Introductory physics: 25%

As we continue developing this test section, these percentages may be adjusted. Additional detail about any adjustments to this section will be posted on the MCAT<sup>2015</sup> website as soon as it is available.

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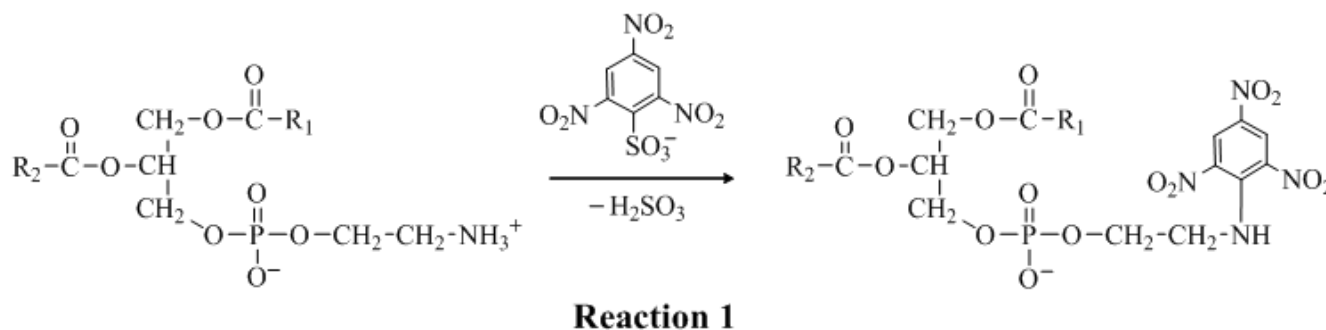
<sup>16</sup> You may also wonder how many questions you'll get about a particular Scientific Inquiry and Reasoning skill in the *Chemical and Physical Foundations of Biological Systems* section of the MCAT<sup>2015</sup> exam. This issue is currently under consideration by test development and content experts and will be shared with the public as soon as it is available.

## Sample Test Questions<sup>17</sup>: *Chemical and Physical Foundations of Biological Systems*

Sample test questions for the *Chemical and Physical Foundations of Biological Systems* section are provided below. The answer key appears below each question, along with the foundational concept, content category, and skill the question is testing. These sample questions will give you an idea of what to expect from this section of the exam.

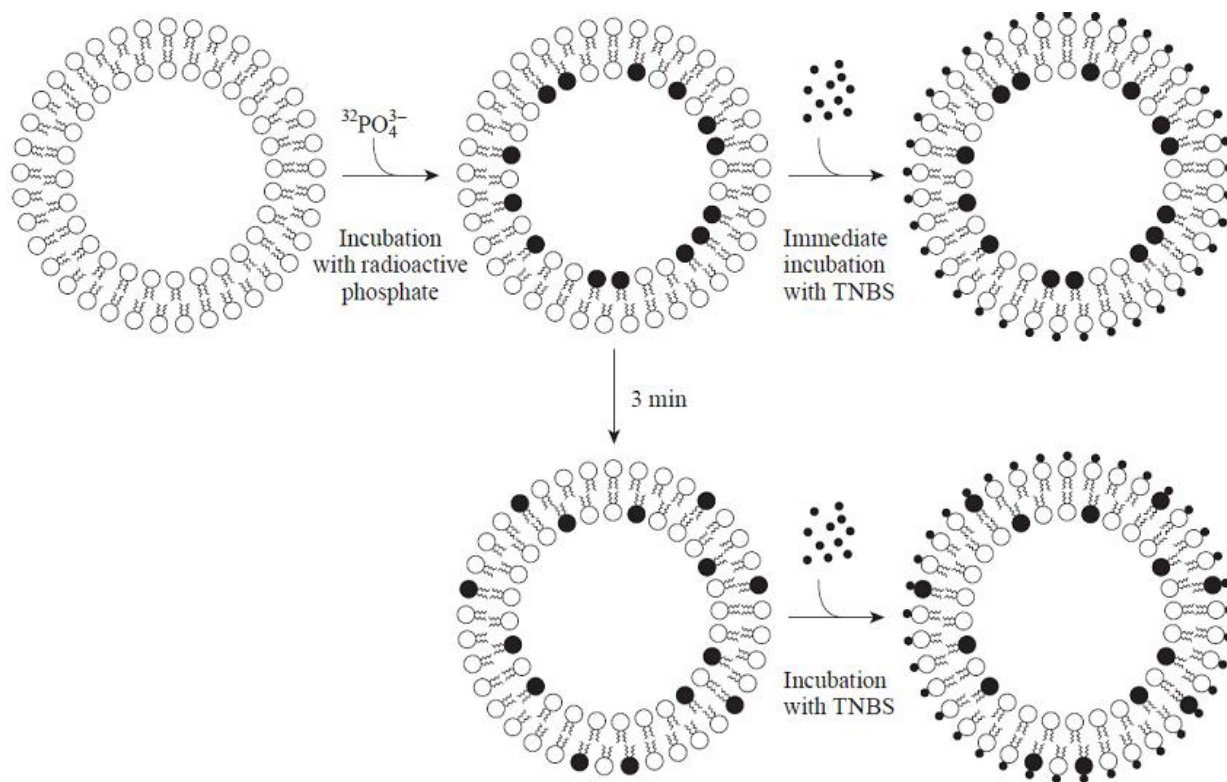
### Sample Passage 1: Questions 1–5

Trinitrobenzene sulfonic acid (TNBS) is a membrane-impermeable reagent that combines with phosphatidylethanolamine (PE) as shown in Reaction 1. Upon reaction, TNBS-labeled PE molecules are frozen on the outer envelope of membranes and do not exchange with other PE molecules on the inner envelope.



Growing bacteria were treated with radioactive <sup>32</sup>P-labeled phosphate (<sup>32</sup>PO<sub>4</sub><sup>3-</sup>) in an effort to identify the location of PE synthesis. In this experiment newly synthesized PE will contain a <sup>32</sup>P label. When growing bacteria are treated with a pulse of radioactive <sup>32</sup>PO<sub>4</sub><sup>3-</sup> followed by immediate treatment with TNBS, almost none of the TNBS-labeled PE contained <sup>32</sup>P. In contrast, if an interval of only three minutes was allowed to elapse between the <sup>32</sup>PO<sub>4</sub><sup>3-</sup> pulse and the TNBS treatment, almost 50% of the <sup>32</sup>P-labeled PE was also TNBS labeled. These results are summarized in Figure 1.

<sup>17</sup> These sample passages and questions have not followed the same review and field-test procedures as do operational test materials.



**Figure 1.** Summary of experiments designed to establish the location of lipid biosynthesis in a bacterial membrane, ○ = unlabeled phosphate, ● = labeled phosphate, • = TNBS molecule (attached to either ○ or ●)

- 1) **The scientists who developed the experimental protocol described in the passage chose TNBS over many potential candidates to label PE molecules. What characteristic about the rate of reaction between TNBS and outer envelope PE molecules allowed the experiment to provide useful data? The rate of TNBS reaction with outer envelope PE molecules is:**
- faster than the rate of exchange between inner and outer envelope PE molecules.
  - slower than the rate of phosphate transport across the membrane.
  - facilitated by the additional phosphate present in solution.
  - easily measured by the method of initial rates.

Answer: A

Foundational Concept: 5

Content Category: 5E

Skill: 3

**2) Which statement correctly describes both  $\text{PO}_4^{3-}$  and TNBS?**

- A. Both TNBS and  $\text{PO}_4^{3-}$  are hydrophobic.
- B. TNBS is hydrophobic and  $\text{PO}_4^{3-}$  is hydrophilic.
- C.  $\text{PO}_4^{3-}$  is hydrophobic and TNBS is hydrophilic.
- D. Both TNBS and  $\text{PO}_4^{3-}$  are hydrophilic.

Answer: D

Foundational Concept: 5

Content Category: 5B

Skill: 2

**3) In Reaction 1, what is a possible structure for either  $\text{R}_1$  or  $\text{R}_2$  of the reactant?**

- A.  $\text{CH}_3$
- B.  $\text{NH}_2$
- C.  $(\text{CH}_2)_{15}\text{CH}_3$
- D.  $(\text{CH}_2\text{O})_{10}\text{CH}_3$

Answer: C

Foundational Concept: 5

Content Category: 5D

Skill: 1

**4) The  $^{32}\text{P}$  label was generated from naturally occurring phosphorous by:**

- A. removing a neutron from the nucleus.
- B. adding a proton to the nucleus.
- C. adding three electrons to the atom.
- D. adding a neutron to the nucleus.

Answer: D

Foundational Concept: 4

Content Category: 4E

Skill: 1

- 5) A scientist proposed that the  $^{32}\text{P}$  label was entering PE molecules by direct exchange (swapping phosphate groups with those found in solution) and NOT through synthesis of new PE by bacterial cells. What experimental modification can show this is NOT the case?**
- A. Introduce TNBS prior to pulsing with  $^{32}\text{PO}_4^{3-}$ .
  - B. Measure the rate of incorporation of  $^{32}\text{PO}_4^{3-}$  into acellular PE.
  - C. Use mouse cell cultures instead of bacterial cells.
  - D. Decrease the concentration of  $^{32}\text{PO}_4^{3-}$  and observe the effect on incorporation rate.

Answer: B

Foundational Concept: 5

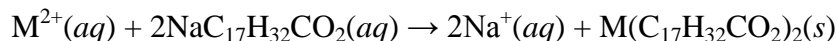
Content Category: 5D

Skill: 3

## Sample Passage 2: Questions 6–10

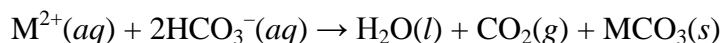
Hard water contains cations that form precipitates with soap or upon boiling. The principle hardness ions are  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{Fe}^{2+}$ . There are two major drawbacks of hard water.

First, the  $\text{M}^{2+}$  ions reduce the effectiveness of common soaps, which contain the sodium salts of organic acids with long carbon chains. An example is sodium stearate,  $\text{C}_{17}\text{H}_{32}\text{CO}_2\text{Na}$  (MW = 306). The reaction between soaps and hardness ions yields insoluble precipitates through Reaction 1. Removal of stearate from the solution eliminates the effectiveness of the soap.



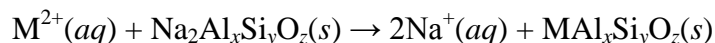
### Reaction 1

Second, hard water produces boiler scale, a layer of insoluble carbonates formed by Reaction 2 that lines the inner walls of pipes and hot-water boilers. Deposits of this type are especially bad in hot water and are poor conductors of heat.



### Reaction 2

It is important that the cations responsible for hard water be removed before the water is heated or used for washing. Water softening, the removal of hardness ions from water, can be accomplished in several ways. One method is the ion exchange process in which water is passed through a column containing solid sodium aluminosilicates. Sodium aluminosilicates are high surface area three-dimensional extended solids with  $-\text{ONa}$  groups at the surface.



### Reaction 3

6) The hardness ions described in the passage are:

- A. alkaline earth metals.
- B. strongly acidic cations.
- C. formed in nature by reduction of other cations.
- D. derived from atoms upon loss of two electrons.

Answer: D

Foundational Concept: 4

Content Category: 4E

Skill: 1



**7) What happens to the pH of a soapy solution as a result of the introduction of hardness ions?**

- A. The pH increases as  $[H^+]$  increases.
- B. The pH is not changed since no acid-base reaction occurs.
- C. The pH decreases as  $[OH^-]$  decreases.
- D. The effect on pH depends on the identity  $M^{2+}$ .

Answer: C

Foundational Concept: 5

Content Category: 5A

Skill: 2

**8) Soaps are chemically modified natural products that can be derived from all of the following EXCEPT:**

- A. fatty acids.
- B. cholesterol.
- C. triacylglycerols.
- D. phospholipids.

Answer: B

Foundational Concept: 5

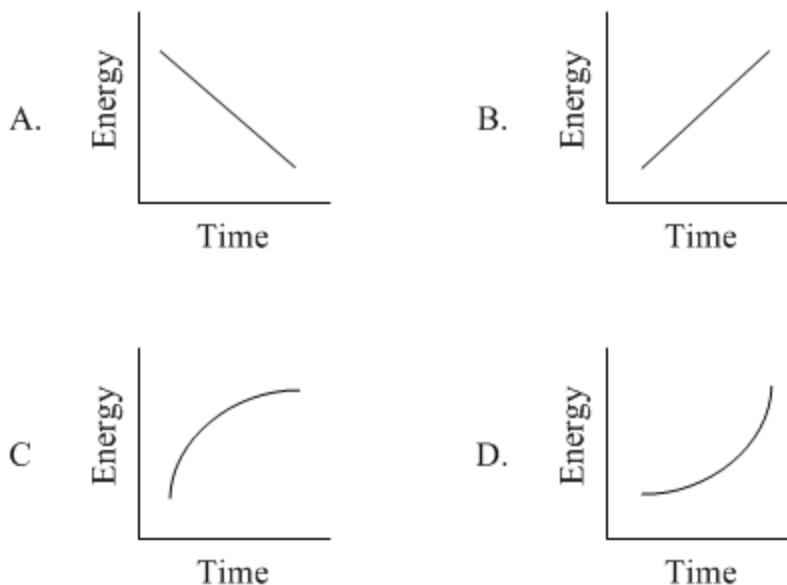
Content Category: 5D

Skill: 2

- 9) A pump is used to force an aqueous solution through a pipe at high temperature according to Poiseuille's Law:

$$\text{Flow rate} = \frac{\Delta P \pi r^4}{8L\eta}$$

Where  $\Delta P$  is the pressure difference applied by the pump,  $r$  is the radius of the pipe,  $L$  is the length of the pipe, and  $\eta$  is the viscosity of the solution. Which graph depicts the rate of energy consumed over time in order to maintain constant flow through a pipe subject to boiler scale?



Answer: D

Foundational Concept: 4

Content Category: 4B

Skill: 4

- 10) Which experimental approach can be used to analyze the metal content of soapy precipitate produced by Reaction 1? Dissolve the solid in a known volume of:

- A. 0.1 M  $\text{NaHCO}_3(aq)$ , then titrate with standardized 0.1 M  $\text{HCl}(aq)$  using an indicator.
- B. 0.1 M  $\text{NaOH}(aq)$ , then titrate with standardized 0.1 M  $\text{HCl}(aq)$  using an indicator.
- C. 0.1 M  $\text{NaCl}(aq)$ , then titrate with standardized 0.1 M  $\text{NaOH}(aq)$  using an indicator.
- D. 0.1 M  $\text{HCl}(aq)$ , then titrate with standardized 0.1 M  $\text{NaOH}(aq)$  using an indicator.

Answer: D

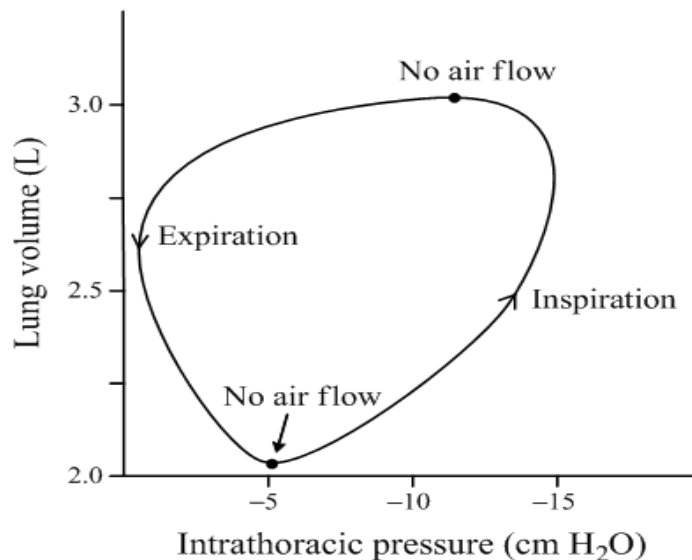
Foundational Concept: 5

Content Category: 5A

Skill: 3

**Sample Questions 11–14** (these questions are not associated with passages)

**11) 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

Answer: A

Foundational Concept: 4

Content Category: 4B

Skill: 4

**12) Human speech is generated in the vocal chords as the lungs push air past them. What property of the vocal chords is changed so that the frequency of sound can be altered?**

- A. Volume
- B. Density
- C. Tension
- D. Number

Answer: C

Foundational Concept: 4

Content Category: 4D

Skill: 2

13) The radius of the aorta is about 1.0 cm and blood passes through it at a velocity of 30 cm/s. A typical capillary has a radius of about  $4 \times 10^{-4}$  cm with blood passing through at a velocity of  $5 \times 10^{-4}$  m/s. Using this data, what is the approximate number of capillaries in a human body?

- A.  $1 \times 10^4$
- B.  $2 \times 10^7$
- C.  $4 \times 10^9$
- D.  $7 \times 10^{12}$

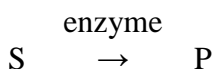
Answer: C

Foundational Concept: 4

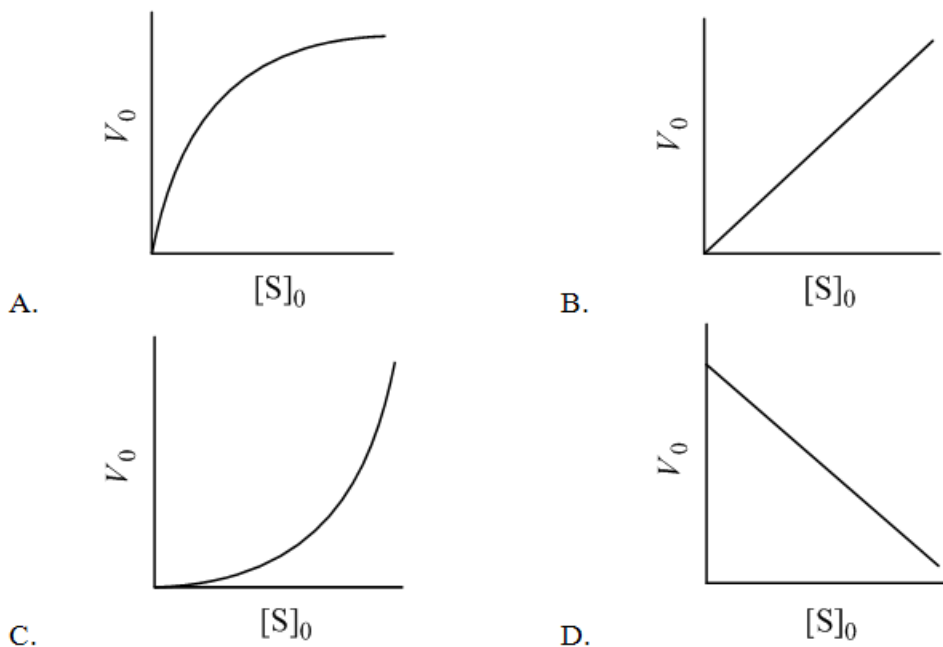
Content Category: 4B

Skill: 2

14) A researcher measures the initial rate ( $V_0 = \Delta[P]/\Delta t$ ) of an enzymatically catalyzed reaction at a variety of substrate concentrations  $[S]_0$ .



Which graph best represents the observed relationship between  $[S]_0$  versus  $V_0$ ?



Answer: A

Foundational Concept: 5

Content Category: 5E

Skill: 1

## Chapter 6: What will the *Psychological, Social, and Biological Foundations of Behavior* Section Test?

The *Psychological, Social, and Biological Foundations of Behavior* section asks you to solve problems by combining your knowledge of foundational concepts with your scientific inquiry and reasoning skills. This section tests your understanding of the ways in which psychological, social, and biological factors influence perceptions and reactions to the world; behavior and behavior change; what people think about themselves and others; the cultural and social differences that influence well-being; and the relationships between social stratification, access to resources, and well-being.

The *Psychological, Social, and Biological Foundations of Behavior* section emphasizes concepts that tomorrow's doctors need to know in order to serve a more diverse population and have a clear understanding of the impact of behavior on health. Further, it communicates the need for future physicians to be prepared to deal with the human and social issues of medicine.

### Descriptions of Foundational Concepts and Content Categories

The following are detailed explanations of each foundational concept and related content category tested by the *Psychological, Social, and Biological Foundations of Behavior* section. As with the natural sciences sections, content lists describing specific topics and subtopics that define each content category are provided. The same content list is provided to item writers who develop the content of the exam. Here is an excerpt from the content list:

#### **EXAMPLE**

#### **Self-presentation and Interacting with Others (PSY, SOC) ←——Topic**

- Expressing and detecting emotion ←——Subtopic
  - Gender shapes expression
  - Culture shapes expression
- Impression management
  - Front stage vs. back stage self (Dramaturgical approach) (SOC)
- Verbal and nonverbal communication
- Animal signals and communication (PSY, BIO)

The abbreviations found in parentheses indicate the course(s) in which undergraduate students at many colleges and universities learn about the topics and associated subtopics. The course abbreviations are:

- PSY = one semester of introductory psychology
- SOC = one semester of introductory sociology
- BIO = two-semester sequence of introductory biology

In preparing for the MCAT<sup>2015</sup> exam, you will be responsible for learning the topics and associated subtopics at the levels at which they are taught in the courses listed in parentheses.

A small number of subtopics have course abbreviations indicated in parentheses. In those cases, you are responsible only for learning the subtopics as they are taught in the course(s) indicated.

Using the excerpt above as an example:

- You are responsible for learning about the topic “Self-presentation and Interacting with Others,” at the level at which it is taught in a typical introductory psychology course AND in a typical introductory sociology course.
- You are responsible for learning about the sub-subtopic “Front stage vs. back stage self (Dramaturgical approach)” **only** at the level at which it is taught in a typical introductory sociology course.
- You are responsible for learning about the subtopic “Animal signals and communication” **only** at the level at which it is taught in a typical introductory psychology course AND in a typical introductory biology course.

Remember that course content at your school may differ from course content at other colleges and universities. The topics and subtopics that are described in this chapter may be covered in courses with different titles than those that are listed. Your pre-health advisor and faculty are important resources for questions about course content.

## *Psychological, Social, and Biological Foundations of Behavior*

### **Foundational Concept 6**

Biological, psychological, and socio-cultural factors influence the ways that individuals perceive, think about, and react to the world.

The way in which we sense, perceive, think about, and react to stimuli affects our experiences. Foundational Concept 6 focuses on these components of experience, starting with the initial detection and perception of stimuli through cognition, and continuing to emotion and stress.

#### **Content Categories**

- *Category 6A* focuses on the detection and perception of sensory information.
- *Category 6B* focuses on cognition, including our ability to attend to the environment, think about and remember what we experience, and use language to communicate with others.
- *Category 6C* focuses on how we process and experience emotion and stress.

These are the building blocks medical students need in order to learn about the ways in which cognitive and perceptual processes influence their understanding of health and illness.

#### **Please Note**

Topic lists in the *Preview Guide for MCAT<sup>2015</sup>* are preliminary. They will likely be refined (in minor ways) as testing experts continue working on the exam.

The MCAT<sup>2015</sup> website will be updated as information becomes available: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

## Content Category 6A: *Sensing the environment*

Psychological, socio-cultural, and biological factors affect our sensation and perception of the world. All sensory processing begins with first detecting a stimulus in the environment through sensory cells, receptors, and biological pathways.

After collecting sensory information, we then interpret and make sense of it. Although sensation and perception are distinct functions, they are both influenced by psychological, social, and biological factors and therefore become almost indistinguishable in practice. This complexity is illuminated by examining human sight, hearing, touch, taste, and smell.

The content in this category covers sensation and perception across all five human senses. The topics and subtopics in this category are:

### Sensory Processing (PSY, BIO)

- Sensation
  - Thresholds
  - Weber's Law (PSY)
  - Signal detection theory (PSY)
  - Sensory adaptation
- Sensory receptors
  - Sensory pathways
  - Types of sensory receptors

### Vision (PSY, BIO)

- Structure and function of the eye
- Visual processing
  - Visual pathways in the brain
  - Parallel processing (PSY)
  - Feature detection (PSY)

#### Please Note

Topics that appear on multiple content lists will be treated differently. Questions will focus on the topics as they are described in the narrative for the content category.

### Hearing (PSY, BIO)

- Auditory processing
  - Auditory pathways in the brain
- Sensory reception by hair cells (PSY)

### Other Senses (PSY, BIO)

- Somatosensation
  - Pain perception (PSY)
- Taste
  - Taste buds/chemoreceptors that detect specific chemicals
- Smell
  - Olfactory cells/chemoreceptors that detect specific chemicals
  - Pheromones (BIO)
  - Olfactory pathways in the brain (BIO)
- Kinesthetic sense (PSY)
- Vestibular sense



## Perception (PSY)

- Perception
  - Bottom-up/Top-down processing
  - Perceptual organization (e.g., depth, form, motion, constancy)
  - Gestalt principles

## **Content Category 6B: *Making sense of the environment***

The way we think about the world depends on our awareness, thoughts, knowledge, and memories. It is also influenced by our ability to solve problems, make decisions, form judgments, and communicate. Psychological, socio-cultural, and biological influences determine the development and use of these different yet convergent processes.

Biological factors underlie the mental processes that create our reality, shape our perception of the world, and influence the way we perceive and react to every aspect of our lives. The content in this category covers critical aspects of cognition — including consciousness, cognitive development, problem solving and decision making, intelligence, memory, and language. The topics and subtopics in this category are:

### **Attention (PSY)**

- Selective attention
- Divided attention

### **Cognition (PSY)**

- Information-processing model
- Cognitive development
  - Piaget’s stages of cognitive development
  - Cognitive changes in late adulthood
  - Role of culture in cognitive development
  - Influence of heredity and environment on cognitive development
- Biological factors that affect cognition (PSY, BIO)
- Problem solving and decision making (PSY, BIO)
  - Types of problem solving
  - Barriers to effective problem solving
  - Approaches to problem solving
  - Heuristics, biases, intuition, and emotion
    - Overconfidence and belief perseverance
- Intellectual functioning
  - Multiple definitions of intelligence
  - Influence of heredity and environment on intelligence
  - Variations in intellectual ability

### **Consciousness (PSY)**

- States of consciousness
  - Alertness (PSY, BIO)
  - Sleep
    - Stages of sleep
    - Sleep cycles and changes to sleep cycles
    - Sleep and circadian rhythms (PSY, BIO)
    - Dreaming
    - Sleep disorders
  - Hypnosis and meditation

- Consciousness altering drugs
  - Types of consciousness altering drugs and their effects on the nervous system and behavior
  - Drug addiction and the reward pathway in the brain

### **Memory (PSY)**

- Encoding
  - Process of encoding information
  - Processes that aid in encoding memories
- Storage
  - Types of memory storage (e.g., sensory, working, long-term)
  - Semantic networks and spreading activation
- Retrieval
  - Recall, recognition, and relearning
  - Retrieval cues
  - The role of emotion in retrieving memories
- Forgetting
  - Aging and memory
  - Memory dysfunctions (e.g., Alzheimer's disease, Korsakoff's syndrome)
  - Decay
  - Interference
  - Memory construction and source monitoring
- Changes in synaptic connections underlie memory and learning (PSY, BIO)
  - Neural plasticity
  - Memory and learning
  - Long-term potentiation

### **Language (PSY)**

- Theories of language development (e.g., learning, Nativist, Interactionist)
- Influence of language on cognition
- Different brain areas control language and speech (PSY, BIO)

## **Content Category 6C: *Responding to the world***

We experience a barrage of environmental stimuli throughout the course of our lives. In many cases, environmental stimuli trigger physiological responses, such as an elevated heart rate, increased perspiration, or heightened feelings of anxiety. How we perceive and interpret these physiological responses is complex and influenced by psychological, socio-cultural, and biological factors.

Emotional responses, such as feelings of happiness, sadness, anger, or stress are often born out of our interpretation of this interplay of physiological responses. Our experience with emotions and stress not only affects our behavior, but also shapes our interactions with others.

The content in this category covers the basic components and theories of emotion and their underlying psychological, socio-cultural, and biological factors. It also addresses stress, stress outcomes, and stress management. The topics and subtopics in this category are:

### **Emotion (PSY)**

- Three components of emotion (i.e., cognitive, physiological, behavioral)
- Universal emotions (e.g., fear, anger, happiness, surprise, joy, disgust, sadness)
- Adaptive role of emotion
- Theories of emotion
  - James-Lange theory
  - Cannon-Bard theory
  - Schachter-Singer theory
- The role of biological processes in perceiving emotion (PSY, BIO)
  - Generation and experience of emotions involve many brain regions
  - The role of the limbic system in emotion
  - Emotional experiences can be stored as memories that can be recalled by similar circumstances
  - Prefrontal cortex is critical for emotional experience, and is also important in temperament and decision making
  - Emotion and the autonomic nervous system
  - Physiological markers of emotion (signatures of emotion)

### **Stress (PSY)**

- The nature of stress
  - Appraisal
  - Different types of stressors (e.g., cataclysmic events, personal, etc.)
  - Effects of stress on psychological functions
- Stress outcomes/response to stressors
  - Physiological (PSY, BIO)
  - Emotional
  - Behavioral
- Managing stress (e.g., exercise, relaxation techniques, spirituality, etc.)

## *Psychological, Social, and Biological Foundations of Behavior*

### **Foundational Concept 7**

Biological, psychological, and socio-cultural factors influence behavior and behavior change.

Human behavior is complex and often surprising, differing across individuals in the same situation and within an individual across different situations. A full understanding of human behavior requires knowledge of the interplay between psychological, socio-cultural, and biological factors that are related to behavior. This interplay has important implications for the way we behave and the likelihood of behavior change.

Foundational Concept 7 focuses on individual and social determinants of behavior and behavior change.

#### **Content Categories**

- *Category 7A* focuses on the individual psychological and biological factors that affect behavior.
- *Category 7B* focuses on how social factors, such as groups and culture, affect behavior.
- *Category 7C* focuses on how learning affects behavior, as well as the role of attitude theories in behavior and behavior change.

These are the building blocks medical students need in order to learn about behavioral pathways for promoting health and preventing disease, including behaviors that pose a risk to health. Students entering medical school with this knowledge will also be better equipped to learn about interventions that help patients adopt healthy behaviors.

## **Content Category 7A: *Individual influences on behavior***

A complex interplay of psychological and biological factors shapes behavior. Biological structures and processes serve as the pathway by which bodies carry out activities. They also affect predispositions to behave in certain ways, shape personalities, and influence the likelihood of developing psychological disorders. Psychological factors also affect behavior, and consequently, health and well-being.

The content in this category covers biological bases of behavior, including the effect of genetics and how the nervous and endocrine systems affect behavior. It also addresses how personality, psychological disorders, motivation, and attitudes affect behavior. Some of these topics are learned in the context of non-human animal species. The topics and subtopics in this category are:

### **Biological Bases of Behavior (PSY, BIO)**

- The nervous system
  - Neurons
    - The reflex arc
  - Neurotransmitters
  - Peripheral nervous system
  - Central nervous system
    - The brain
      - The brainstem
      - The cerebellum
      - The diencephalon (BIO)
      - The cerebrum
      - Control of voluntary movement in the cerebral cortex
      - Information processing in the cerebral cortex
      - Lateralization of cortical functions
      - Methods of studying the brain
- Neurons communicate and influence behavior (PSY)
- Influence of neurotransmitters on behavior (PSY)
- The endocrine system
  - Components of the endocrine system
  - Effects of the endocrine system on behavior
- Behavioral genetics
  - Genes, temperament, and heredity
  - Adaptive value of traits and behaviors
  - Interaction between heredity and environmental influences
- Genetic and environmental factors contribute to the development of behaviors
  - Experience and behavior (PSY)
  - Regulatory genes and behavior (BIO)
  - Genetically based behavioral variation in natural populations
- Human physiological development (PSY)
  - Prenatal development
  - Motor development
  - Developmental changes in adolescence

## Personality (PSY)

- Theories of personality
  - Psychoanalytic perspective
  - Humanistic perspective
  - Trait perspective
  - Social cognitive perspective
  - Biological perspective
  - Behaviorist perspective
- Situational approach to explaining behavior

## Psychological Disorders (PSY)

- Understanding psychological disorders
  - Biomedical vs. biopsychosocial approaches
  - Classifying psychological disorders
  - Rates of psychological disorders
- Types of psychological disorders
  - Anxiety disorders
  - Somatoform disorders
  - Mood disorders
  - Schizophrenia
  - Dissociative disorder
  - Personality disorders
- Biological bases of nervous system disorders (PSY, BIO)
  - Schizophrenia
  - Depression
  - Alzheimer's disease
  - Parkinson's disease
  - Stem cell-based therapy to regenerate neurons in CNS (BIO)

## Motivation (PSY)

- Factors that influence motivation
  - Instinct
  - Arousal
  - Drives
    - Negative feedback systems (PSY, BIO)
  - Needs
- Theories that explain how motivation affects human behavior
  - Drive reduction theory
  - Incentive theory
  - Other: cognitive and need based theories
- Application of theories of motivation to understand behaviors (e.g., eating, sexual, drug and alcohol use, etc.)
  - Biological factors in regulation of these motivational processes
  - Socio-cultural factors in regulation of these motivational processes

## **Attitudes (PSY)**

- Components of attitudes (i.e., cognitive, affective, and behavioral)
- The link between attitudes and behavior
  - Processes by which behavior influences attitudes (e.g., foot-in-the door phenomenon, role-playing effects)
  - Processes by which attitudes influence behavior
  - Cognitive dissonance theory



## **Content Category 7B: *Social processes that influence human behavior***

Many social processes influence human behavior; in fact, the mere presence of other individuals can influence our behavior. Groups, societal norms, and culture also exert influence over our behavior. Oftentimes, social processes influence our behavior through unwritten rules that define acceptable and unacceptable behavior in society.

Our understanding of groups and societal norms is learned through the process of socialization. What we learn about the groups and society to which we belong affects our behavior and influences our perceptions and interactions with others.

The content in this category covers how the presence of others, group processes, culture, and socialization shape our behavior. The topics and subtopics in this category are:

### **How the Presence of Others Affects Individual Behavior (PSY)**

- Social facilitation
- Deindividuation
- Bystander effect
- Social loafing
- Peer pressure (PSY, SOC)

### **Group Processes (PSY, SOC)**

- Group polarization (PSY)
- Groupthink

### **Culture (PSY, SOC)**

- Assimilation
- Multiculturalism (SOC)
- Subcultures (SOC)

### **Socialization (PSY, SOC)**

- Definition of socialization (SOC)
- Norms
- Agents of socialization (e.g., the family, mass media, peers, workplace) (SOC)
- Stigma and deviance (SOC)
- Conformity and obedience

## **Content Category 7C: *Attitude and behavior change***

Learning is a relatively permanent change in behavior brought about by experience. There are a number of different types of learning, which include habituation as well as associative, observational, and social learning.

Although people can learn new behaviors and change their attitudes, psychological, environmental, and biological factors influence whether those changes will be short-term or long-term. Understanding how people learn new behaviors, change their attitudes, and the conditions that affect learning helps us understand behavior and interactions with others.

The content in this category covers learning and theories of attitude and behavior change. This includes the Elaboration Likelihood Model, theories of information processing, and Social Cognitive Theory. The topics and subtopics in this category are:

### **Habituation and Dishabituation (PSY)**

#### **Associative Learning (PSY)**

- Classical conditioning (PSY, BIO)
  - Neutral, conditioned, and unconditioned stimuli
  - Conditioned and unconditioned response
  - Processes: acquisition, extinction, spontaneous recovery, generalization, discrimination
- Operant conditioning (PSY, BIO)
  - Processes of shaping and extinction
  - Types of reinforcement: positive, negative, primary, conditional
  - Reinforcement schedules: fixed-ratio, variable-ratio, fixed-interval, variable-interval
  - Punishment
  - Escape and avoidance learning
- Cognitive processes that affect associative learning
- Biological factors that affect associative learning
  - Innate behaviors are developmentally fixed
  - Learned behaviors are modified based on experiences
  - Development of learned behaviors (PSY, BIO)

#### **Observational Learning (PSY)**

- Modeling
- Biological processes that affect observational learning
  - Mirror neurons
  - Role of the brain in experiencing vicarious emotions
- Applications of observational learning to explain individual behavior

#### **Theories of Attitude and Behavior Change (PSY)**

- Elaboration Likelihood Model
  - Information processing routes to persuasion (e.g., central and peripheral route processing)
- Social Cognitive theory
- Factors that affect attitude change (e.g., changing behavior, characteristics of the message and target, social factors)

## *Psychological, Social, and Biological Foundations of Behavior*

### **Foundational Concept 8**

Psychological, socio-cultural, and biological factors influence the way we think about ourselves and others.

The relationship between how people think about themselves and others is complex — and most apparent when dealing with social situations. The interplay between our thoughts about ourselves, thoughts about others, and our biology has important implications for our sense of self and interpersonal relationships.

Foundational Concept 8 focuses on the cognitive and physical components of relationships, both of which influence how we behave with others.

#### **Content Categories**

- *Category 8A* focuses on the notion of self and identity formation.
- *Category 8B* focuses on the attitudes and beliefs that affect social interactions.
- *Category 8C* focuses on the actions and processes underlying social interactions.

These are the building blocks medical students need in order to learn about interacting and collaborating with patients, their families, and other health professionals, as well as the factors that influence patient-provider interactions.

## **Content Category 8A: *Self-identity***

The *self* refers to the thoughts and beliefs we have about ourselves. Our notion of self is complex and multifaceted. It includes gender, racial, and ethnic identities, as well as beliefs about our ability to accomplish tasks and exert control over different situations.

Our notion of self develops over time and is shaped by a variety of factors, including society, culture, individuals and groups, and our unique experiences. How we view ourselves influences our perceptions of others, and by extension, our interactions with them.

The content in this category covers the notions of self-concept and identity, along with the role of self-esteem, self-efficacy, and locus of control in the development of self-concept. Identity formation, including developmental stages and the social factors that affect identity formation, is also covered here. Theories are included to provide historical context for the field of identity formation. The topics and subtopics in this category are:

### **Self-Concept and Identity (PSY, SOC)**

- Definitions of self-concept, identity, and social identity
- The role of self-esteem, self-efficacy, and locus of control in self-concept and self-identity (PSY)
- Different types of identities (e.g., race/ethnicity, gender, age, sexual orientation, class)

### **Formation of Identity (PSY, SOC)**

- Stages of identity development
  - Theories of developmental stages (e.g., Erikson, Vygotsky, Kohlberg, Freud) (PSY)
- Influence of social factors on identity formation
  - Influence of individuals (e.g., imitation, role-taking)
  - Influence of group (e.g., reference group)
- Influence of culture and socialization on identity formation

## **Content Category 8B: *Social thinking***

*Social thinking* refers to the ways in which we view others and our environment, as well as how we interpret others' behaviors. A variety of factors—personality, environment, and culture—factor into the beliefs and attitudes we develop.

Our beliefs and attitudes about others and the environment also shape the way we interact with each other. To interact with others, we need to interpret different aspects of a situation, including our perception of ourselves, the behavior of others, and the environment.

The content in this category covers our attitudes about others and how those attitudes are developed, attribution theory and how our perceptions of culture and environment affect attributions, and the influence of our attitudes on different groups—prejudice, stereotypes, and ethnocentrism—which may influence our interactions with group members. The topics and subtopics in this category are:

### **Attributing Behavior to Persons or Situations (PSY)**

- Attribution theory
  - Fundamental attribution error
  - How culture affects attributions
- How self-perceptions shape our perceptions of others
- How perceptions of the environment shape our perceptions of others

### **Prejudice and Bias (PSY, SOC)**

- Definition of prejudice
- Processes that contribute to prejudice
  - Power, prestige, and class (SOC)
  - The role of emotion in prejudice (PSY)
  - The role of cognition in prejudice (PSY)
- Stereotypes
- Ethnocentrism (SOC)
  - In-group and out-group
  - Ethnocentrism vs. cultural relativism

### **Processes Related to Stereotypes (PSY)**

- Self-fulfilling prophecy
- Stereotype threat

## **Content Category 8C: *Social interactions***

Humans are social beings by nature. Though the sentiment is simple, the actions and processes underlying and shaping our social interactions are not.

The elements of social interaction are important for understanding the mechanisms and processes through which people interact with each other, both individually and within groups. A variety of factors—personality, environment, culture, and biology—affect how we present ourselves to others and how we treat them. For example, perceptions of prejudice and stereotypes can lead to acts of discrimination, whereas positive attitudes about others can lead to the provision of help and social support.

The content in this category covers the mechanisms of self-presentation and social interaction including expressing and detecting emotion, impression management, communication, and the biological underpinning of social behavior. The topics and subtopics in this category are:

### **Elements of Social Interaction (PSY, SOC)**

- Statures (SOC)
- Roles
- Groups
- Networks (SOC)
- Organizations (SOC)

### **Self-presentation and Interacting with Others (PSY, SOC)**

- Expressing and detecting emotion
  - Gender shapes expression
  - Culture shapes expression
- Impression management
  - Front stage vs. back stage self (Dramaturgical approach) (SOC)
- Verbal and nonverbal communication
- Animal signals and communication (PSY, BIO)

### **Social Behavior (PSY)**

- Attraction
- Aggression
- Attachment
- Social support
- Biological explanations of social behavior in animals (PSY, BIO)
  - Foraging behavior (BIO)
  - Mating behavior and mate choice
  - Applying game theory (BIO)
  - Altruism
  - Inclusive fitness (BIO)

### **Discrimination (PSY, SOC)**

- Individual vs. institutional discrimination (SOC)
- The relationship between prejudice and discrimination
- How power, prestige, and class facilitate discrimination (SOC)

*Psychological, Social, and Biological Foundations of Behavior*

**Foundational Concept 9**

Cultural and social differences influence well-being.

Societal structure, culture, and demographic factors influence peoples' health and well-being. Knowledge about basic sociological frameworks, social structures, social institutions, culture, and demographic characteristics of societies is important, as is the ability to understand how they shape peoples' lives and their daily interactions.

Foundational Concept 9 focuses on societal variables and processes that influence our lives.

**Content Categories**

- *Category 9A* focuses on the link between social structures and human interactions.
- *Category 9B* focuses on the demographic characteristics and processes that define a society.

Medical students will build upon these concepts, learning about the ways in which demographics and social context influence healthcare and are potential determinants of healthcare outcomes. Knowledge of these concepts will prepare students to learn about the ways in which patients' backgrounds and experiences influence their responses and expectations in regard to healthcare, interactions with providers, and health outcomes.

## **Content Category 9A: *Understanding social structure***

Social structure organizes all human societies. Elements of social structure include social institutions and culture. These elements are linked in a variety of ways and shape our experiences and interactions with others—a process that is reciprocal.

The content in this category provides a foundation for understanding social structure and institutions, and how and why people interact within and among societies. It covers the components of social structure, theoretical approaches to studying society, specific social institutions relevant to the context of student preparation for medical school, and the construct of culture. The topics and subtopics in this category are:

### **Theoretical Approaches (SOC)**

- Functionalism
- Conflict theory
- Symbolic interactionism
- Social constructionism

### **Social Institutions (SOC)**

- Education
- Family
- Religion
- Government and economy
- Health and medicine

### **Culture (SOC)**

- Material culture
- Symbolic culture
  - Language and symbols
  - Values and beliefs (PSY, SOC)
  - Norms and rituals (PSY, SOC)
- Culture and social groups (PSY, SOC)
- Evolution and human culture (PSY, BIO)



## **Content Category 9B: *Demographic characteristics and processes***

In order to understand the structure of a society, it is important to understand the demographic characteristics and processes which define it. Knowledge of the elements of social interaction and the demographic structure of societies helps us comprehend the distinct processes and mechanisms through which social interaction occurs.

The content in this category includes the elements of social interaction, which are important for understanding the mechanisms and processes through which people interact with each other, both individually and within groups. It addresses the important demographic variables at the core of understanding societies. The topics and subtopics in this category are:

### **Demographic Structure of Society (SOC)**

- Age
- Gender
- Race and ethnicity
- Immigration status
- Sexual orientation

### **Demographic Shifts and Social Change (SOC)**

- Demographic transition
- Fertility, migration, and mortality
- Social movements
- Globalization
- Urbanization

*Psychological, Social, and Biological Foundations of Behavior*

**Foundational Concept 10**

Social stratification and access to resources influence well-being.

Social stratification and inequity affect all human societies, and shape the lives of all individuals by affording privileges to some and positioning others at a disadvantage.

**Content Category**

- *Category 10A* focuses on a broad understanding of social class, including theories of stratification, social mobility, and poverty.

In medical school, students will learn the ways in which social stratification influences healthcare, and how these influences are potential determinants of healthcare outcomes. Knowledge of these concepts will prepare students to learn about the ways patients' social class and living conditions affect their access to healthcare, interactions with providers, and health outcomes.

## **Content Category 10A: *Social inequality***

Barriers to the access of institutional resources exist for the segment of the population that is disenfranchised, and/or lacks power within a given society. Barriers to access might include: language, geographic location, socio-economic status, immigration status, and racial/ethnic identity. Institutionalized racism and discrimination are also factors which prevent some groups from obtaining equal access to resources.

The content in this category covers environmental justice—which addresses the intersection of inequality and environmental issues—and health disparities in relation to class, race/ethnicity, and gender. The topics and subtopics in this category are:

### **Spatial Inequality (SOC)**

- Residential segregation (neighborhoods)
- Environmental justice (location and exposure to health risks)
- Global inequalities

### **Social Class (SOC)**

- Aspects of social stratification
  - Class, status, and power
  - Cultural capital and social capital
  - Social reproduction
  - Privilege and prestige
  - Intersections with race, gender and age
- Patterns of social mobility
  - Intergenerational and intragenerational mobility
  - Downward and upward mobility
  - Meritocracy
- Poverty
  - Relative and absolute
  - Social exclusion (segregation and isolation)

### **Health Disparities (SOC)**

- Race, gender, and class inequalities in health

### **Healthcare Disparities (SOC)**

- Race, gender, and class inequalities in healthcare

## Distribution of Questions by Foundational Concept and Discipline

You may wonder how much psychology, sociology, and biology you'll see on this section of the MCAT<sup>2015</sup> exam, or how many questions you'll get about a particular foundational concept. For each test form, you are likely to see questions distributed in the ways that are described below. These are the **approximate** percentages of questions you'll see on a test form for each foundational concept and discipline<sup>18</sup>.

### Foundational Concept:

- 6: 27%
- 7: 33%
- 8: 20%
- 9: 15%
- 10: 5%

### Discipline:

- Introductory psychology: 60%
- Introductory sociology: 30%
- Introductory biology: 10%

As we continue developing this test section, these percentages may be adjusted. Additional detail about any adjustments to this section will be posted on the MCAT<sup>2015</sup> website as soon as it is available.

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<sup>18</sup> You may also wonder how many questions you'll get about a particular Scientific Inquiry and Reasoning skill in the *Psychological, Social, and Biological Foundations of Behavior* section of the MCAT<sup>2015</sup> exam. This issue is currently under consideration by test development and content experts and will be shared with the public as soon as it is available.

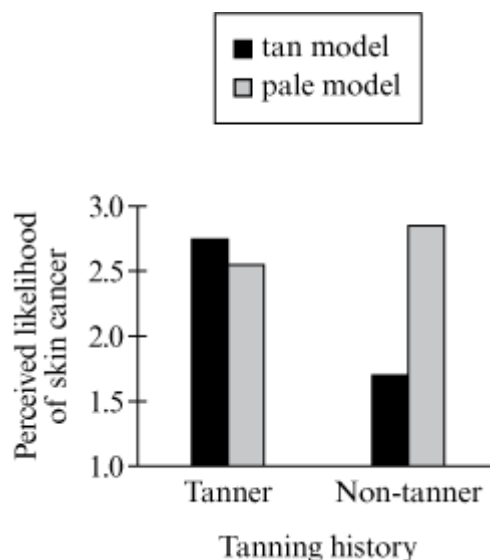
## Sample Test Questions<sup>19</sup>: *Psychological, Social, and Biological Foundations of Behavior*

Sample test questions for the *Psychological, Social, and Biological Foundations of Behavior* section are provided below. The answer key appears below each question, along with the foundational concept, content category, and skill the question is testing. These sample questions will give you an idea of what to expect from this section of the exam.

### Sample Passage 1: Questions 1-5

Perceptions of vulnerability to negative health outcomes influence people’s likelihood of taking preventative health measures and adhering to treatments. Individuals’ perceptions regarding their own vulnerability vary based on cultural factors, media exposure, or self-justification. For instance, smokers who have failed to quit smoking have a tendency to underestimate their likelihood of acquiring lung cancer. In an effort to counteract such shortcomings in risk perception, Canada and other countries require cigarette packs to carry prominent warning labels with large text and graphic pictures of the health consequences of smoking-related diseases. Research suggests that these enhanced warning labels increase attention to the health risks of smoking and can support efforts to quit smoking.

In another area of health risk perception, a study examined comparative optimism in adolescents regarding their vulnerability to skin cancer. Comparative optimism refers to people’s tendency to underestimate their own likelihood of negative outcomes compared to other people. Participants, who were categorized as tanners or non-tanners based on their tanning history, were randomly assigned either to view pictures of tan- or fair-skinned models. Afterwards, the participants were asked to rate their own vulnerability to skin cancer on a 5-point scale on which higher responses indicated greater vulnerability. Figure 1 shows the findings from the study for adolescents aged 13 – 14.



**Figure 1.** Perceptions of vulnerability to acquiring skin cancer when older

<sup>19</sup> These sample passages and question have not followed the same review and field-test procedures as do operational test materials.

*Sources:*

*Adapted from Roberts, M. E., Gibbons, F. X., Gerrard, M., and Alert, M. D. (2011). Optimism and adolescent perception of skin cancer risk. Health Psychology, 30, 810-813.*

*Thrasher, J.F., Hammond, D., Fong, G.T., Arillo-Santillan, E. (2007). Smokers' reactions to cigarette package warnings with graphic imagery and with only text: A comparison between Mexico and Canada. Salud Pública de México 49 (supplement 2): S233-S240.*

**1) According to Figure 1, which group shows the greatest amount of comparative optimism?**

- A. Non-tanners presented with pictures of pale models
- B. Non-tanners presented with pictures of tan models
- C. Tanners presented with pictures of pale models
- D. Tanners presented with pictures of tan models

Answer: B

Foundational Concept: 8

Content Category: 8A

Skill: 4

**2) Under which conditions would people be most likely to experience comparative optimism regarding their own likelihood of contracting HIV?**

- A. When an in-group member has been diagnosed with HIV
- B. When an out-group member has been diagnosed with HIV
- C. When a public figure has been diagnosed with HIV
- D. When a credible physician has been diagnosed with HIV

Answer: B

Foundational Concept: 8

Content Category: 8A

Skill: 2

**3) Given the design of the study described in the passage, which independent variable is manipulated?**

- A. Participants' actual vulnerability to cancer
- B. Participants' perceived vulnerability to cancer
- C. Exposure to tan versus pale models
- D. Tanning history

Answer: C

Foundational Concept: 8

Content Category: 8A

Skill: 3

**4) For global tobacco control efforts described in the first paragraph, graphic depictions of smoking-related illness on warning labels is most likely to be:**

- A. effective as an educational strategy for countries in which a significant proportion of smokers are not literate.
- B. inconsequential as a public health strategy for countries in which there is a growing proportion of young smokers.
- C. illegal in countries with relatively permissive social norms related to cigarette smoking.
- D. supportive of universal cultural values like personal freedom and individual autonomy.

Answer: A

Foundational Concept: 9

Content Category: 9A

Skill: 2

**5) The use of prominent warning labels on cigarette packs best supports which statement?**

- A. The social stigma of risky health behaviors decreases with age.
- B. Peer pressure is the primary motivator in reducing health risks.
- C. Tolerance of risky health behaviors has increased over time.
- D. Social norms about health risks are enforced through sanctions.

Answer: D

Foundational Concept: 9

Content Category: 9A

Skill: 2

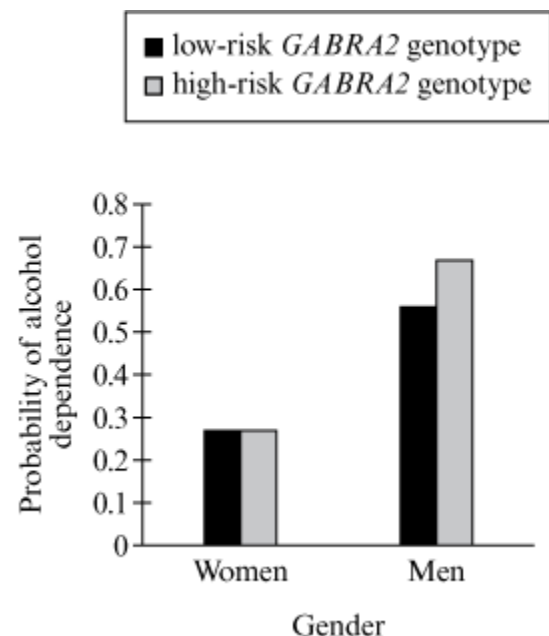
## Sample Passage 2: Questions 6-10

The complex relationship between genetic and environmental factors presents a challenge for researchers studying alcoholism. Genetic predispositions have been implicated in the probability that casual drinking will translate into alcohol dependence. Socio-cultural patterns of drinking shape attitudes and behaviors, contributing to differences in dependence between various groups. For example, men exhibit significantly higher rates of alcohol dependence than women. Studies have suggested that this difference might be, at least in part, attributed to sex hormones. The neurotransmitter involved in the reward pathway, which is known to play a role in addiction, is partially controlled by sex hormones.

The Collaborative Study on the Genetics of Alcoholism (COGA) was conducted using a nonrandom sample of alcohol-dependent participants and community controls. The COGA data suggest the genetic risk of alcohol dependence is linked to specific variants of the *GABRA2* gene.

The protein product of *GABRA2* is the alpha subunit of the GABA receptor protein. Single nucleotide variants of *GABRA2* are associated with low levels of response to the intoxicating effects of alcohol. These variants are not associated with differences in the amino acid composition of the protein but are presumed to participate in the regulation of the amount of *GABRA2* produced.

Identifying the *GABRA2* gene has allowed for better assessment of the relationship between the genetic and environmental factors that contribute to alcohol dependence. For example, COGA data have suggested that childhood material deprivation increases the probability of alcohol dependence among those with the high-risk *GABRA2* genotype. COGA data has also been used to investigate gender differences in alcohol dependence by comparing men and women who carry high- or low-risk genotypes on the *GABRA2* gene. The COGA findings on gender and genetic risk are represented in Figure 1.



**Figure 1.** Predicted probabilities of alcohol dependence by gender and genetic risk



*Source: Adapted from B.A. Pescosolido, B.L. Perry, J.S. Long, and J.K. Martin, in the American Journal of Sociology. ©2008 by The University of Chicago Press.*

**6) Given the relationship between genes and environment in the development of alcoholism, which principle is NOT supported by the passage?**

- A. Genes influence social behavior.
- B. Social factors structure patterns of behavior.
- C. Genes mediate the effects of psychological stressors.
- D. Social factors and genetic factors are unrelated.

Answer: D

Foundational Concept: 9

Content Category: 9A

Skill: 2

**7) Although socio-cultural patterns of drinking vary, excessive alcohol consumption is most accurately described as:**

- A. an excuse for social loafing.
- B. an example of deviant behavior.
- C. a medium for social facilitation.
- D. a sign of peer pressure.

Answer: B

Foundational Concept: 7

Content Category: 7B

Skill: 1

**8) Based upon the passage, what would be the most plausible hypothesis for a study evaluating the effect of socioeconomic status (SES) on the likelihood of alcohol dependence?**

- A. Factors that reflect disadvantaged SES will increase the probability of alcohol dependence among those with the high-risk genotype on *GABRA2*.
- B. Factors related to SES will affect the probability of alcohol dependence only when matched with gender and *GABRA2* genotype.
- C. Factors related to SES will have no effect on the probability of alcohol dependence among those with either high- or low-risk genotype on *GABRA2*.
- D. Factors that reflect advantaged SES will decrease the probability of alcohol dependence among those with the high-risk genotype on *GABRA2*.

Answer: A

Foundational Concept: 10

Content Category: 10A

Skill: 3

**9) If a twin study were conducted to determine the effect of genes independently from the role of social factors, which set of twins would be the most appropriate participants?**

- A. Monozygotic twins reared together
- B. Monozygotic twins adopted into different families
- C. Dizygotic twins reared together
- D. Dizygotic twins adopted into different families

Answer: B

Foundational Concept: 7

Content Category: 7A

Skill: 3

**10) The neurotransmitter described in the passage as being involved in the reward pathway is:**

- A. endorphin.
- B. GABA.
- C. dopamine.
- D. acetylcholine.

Answer: C

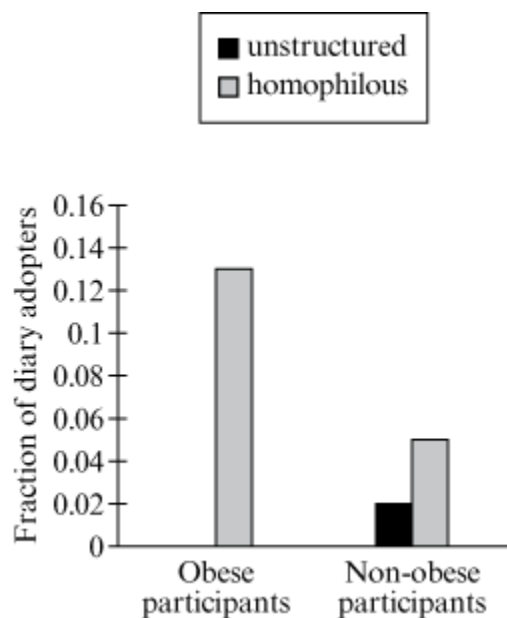
Foundational Concept: 7

Content Category: 7A

Skill: 1

### Sample Passage 3: Questions 11-16

Homophily – the tendency of social contacts to be similar to one another – can have widespread effects on behavior. A recent study examined how similarity in social networks affects health-related behavior. The investigators recruited participants from an online fitness program and divided them into two groups: 1) a homophilous social network, in which participants were matched with health buddies according to age, gender, and body mass index (BMI), and 2) an unstructured social network, in which participants were matched with health buddies at random. Each participant received a notification that their health buddy had started using an Internet-based diet diary, which they would use to share their diet information with their buddies. The participants had to decide whether to adopt an Internet-based diet diary themselves. Figure 1 shows the results of this study.



**Figure 1.** Fraction of obese and non-obese participants who adopted a diary

In follow-up experiments, the researchers pursued several questions regarding health-related behaviors and attitudes. First, they considered factors that might increase the likelihood that subjects would adopt the diet diary. Second, they examined how participants view their own body mass index and that of other individuals, hypothesizing that the self-serving bias could account for these views. Third, they explored the relationship between cognitive dissonance and health-related behaviors. To answer these questions, the researchers gave the participants a survey that asked how much they view exercise and a good diet as important.

Source: Adapted from Centola, D. (2011). An experimental study of homophily in the adoption of health behavior. *Science*, 334, 1269-1272.

**11) Which conclusion is best supported by the findings in Figure 1?**

- A. Non-obese individuals experience more cognitive dissonance than obese individuals.
- B. Participants experience more cognitive dissonance in homophilous groups.
- C. Non-obese individuals conform more than obese individuals.
- D. Participants conform more in homophilous groups.

Answer: D

Foundational Concept: 7

Content Category: 7B

Skill: 4

**12) How could the researchers use the foot-in-the-door technique to increase the participants' likelihood of adopting a diet diary?**

- A. Encourage the participants to sign a petition in support of diet diaries.
- B. Have the participants personally interact with the health buddy who adopted the diet diary.
- C. Tell the participants that the health buddy who adopts the diet diary is a trustworthy health expert.
- D. Tell the participants that most of the people in the experiment have adopted the diet diary

Answer: A

Foundational Concept: 7

Content Category: 7A

Skill: 1

**13) Which statement is NOT compatible with the hypothesis that self-serving bias can account for participants' explanations of their body weights?**

- A. Obese participants view their unhealthy weight as a result of having too many fast food restaurants near home.
- B. Non-obese participants view their healthy weight as a result of having strong will power.
- C. Obese participants view their unhealthy weight as a result of not having time to exercise regularly.
- D. Non-obese participants view their healthy weight as a result of not having any fast food restaurants near their home.

Answer: D

Foundational Concept: 8

Content Category: 8B

Skill: 2

**14) According to the cognitive dissonance theory, which possible finding is most likely?**

- A. Obese participants will start a healthy diet after responding that they view a healthy diet as important.
- B. Non-obese participants will start a healthy diet after responding that they view a healthy diet as important.
- C. Obese participants will de-emphasize the importance of a healthy diet.
- D. Non-obese participants overemphasize the importance of a healthy diet.

Answer: C

Foundational Concept: 7

Content Category: 7A

Skill: 2

**15) If the study were modified to investigate the effect of homophily on the changes in participants' exercise patterns as well as their likelihood of adopting an internet-based diary, how would this change the design of the study?**

- A. A new independent variable would be added.
- B. A new dependent variable would be added.
- C. Levels of an existing independent variable would increase.
- D. The study would become an experimental study.

Answer: B

Foundational Concept: 7

Content Category: 7B

Skill: 3

**16) In helping to explain the results of the study, which other concept would be most similar to a "homophilous" social network?**

- A. Reference group
- B. Secondary group
- C. Out-group
- D. Social group

Answer: A

Foundational Concept: 9

Content Category: 9B

Skill: 1

### Sample Passage 4: Questions 17-21

Low birth weight is a risk factor associated with less favorable health and developmental outcomes later in childhood and adolescence. In the United States, low birth weight is disproportionately prevalent among racial and ethnic minority groups and has been linked to specific environmental and social characteristics of neighborhoods.

Using data from approximately 100,000 live births in Chicago, Illinois, a study found low birth weight to be related to the presence of environmental stressors, such as high violent crime rates, and to a scarcity of social resources, such as limited reciprocal exchange among neighbors. In addition to these neighborhood characteristics, the investigators discovered a spatial distribution to birth weight, observing that mean birth weight in a given neighborhood was systematically related to mean birth weight in adjacent neighborhoods.

Another study used data from a national sample of approximately 1.2 million live births in the United States to investigate the relationship between residential segregation and birth weight for various racial groups. The researchers found that increased racial segregation reduced the chances of low birth weight among Asian-Americans, but marginally increased low birth weight among African-Americans. Moreover, low birth weight among Asian-Americans was less frequent if mothers resided in metropolitan areas in which Asian-American enclaves tended to be clustered. No evidence of a similar clustering effect was found for African-Americans or Latinos. Table 1 displays the percentage of low-birth-weight infants by race of the mother in segregated neighborhoods.

Maternal Race	Percentage of Low-Weight Births
Latino	5.29%
Asian-American	6.10%
African-American	11.05%

**Table 1.** Percentage of Low-Weight Births in Segregated Neighborhoods by Race

Sources:

Adapted from J. Morenoff, “Neighborhood Mechanisms and the Spatial Dynamics of Birth Weight.” ©2003, University of Chicago Press.

E. Walton, “Residential Segregation and Birth Weight among Racial and Ethnic Minorities in the United States” ©2009, American Sociological Association.

**17) Based upon the design of the studies described in the passage, what limits the researchers' ability to draw conclusions about the causal relationship between neighborhood effects and birth weight?**

- A. Birth weight was recorded in kilograms rather than pounds.
- B. Characteristics of the infant subjects were not measured again as they grew older.
- C. Mothers in the sample had not been randomly assigned to neighborhoods.
- D. The first study was conducted in a single city.

Answer: C

Foundational Concept: 7

Content Category: 7B

Skill: 3

**18) Assuming the differences reported in Table 1 are statistically significant, what can be inferred about Latino mothers in the sample?**

- A. Latinos live in less segregated neighborhoods than do Asian-American mothers.
- B. Latinos live in more segregated neighborhoods than do African-American mothers.
- C. Latinos are less likely to have low-birth-weight infants than are African-American mothers.
- D. Latinos are more likely to have low-birth-weight infants than are Asian-Americans mothers.

Answer: C

Foundational Concept: 9

Content Category: 9B

Skill: 4

**19) Based on the description of the first study in the passage, which concept would be most relevant for explaining the relationship between neighborhood characteristics and birth-weight outcomes?**

- A. Poverty
- B. Heredity
- C. Social networks
- D. Socialization

Answer: C

Foundational Concept: 9

Content Category: 9B

Skill: 1

**20) A researcher is interested in determining whether the findings from the first study are mediated by psychological responses to stress. To test this idea, a random sample of mothers from the first study is later given a stress assessment. What is the flaw in this research design?**

- A. The dependent variable is temporally prior to measurement of the independent variable.
- B. The independent variable is temporally prior to measurement of the dependent variable.
- C. The updated sample contains too little variation to draw reliable conclusions.
- D. The updated sample is not representative of the population.

Answer: A

Foundational Concept: 6

Content Category: 6C

Skill: 3

**21) Which independent variable would be most appropriate to investigate the impact of primary groups on the outcome measure discussed in the passage?**

- A. Family structure
- B. Religious affiliation
- C. Occupational status
- D. Population density

Answer: A

Foundational Concept: 9

Content Category: 9B

Skill: 1



### Sample Passage 5: Questions 22-26

Attention Deficit Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder that is indicated by difficulty with attention, response inhibition, and behavioral regulation. Since attention is a multidimensional construct, researchers developed a new test of attentional abilities which examined several diverse tasks. A non-clinical, control group of children was asked to complete these tasks.

In Task 1, children were given a sheet with an array of different shapes, with a star designated as the target shape. On this sheet, 20 targets were distributed among 100 distractors. The children were then asked to find all instances of the target shape among different distractors as quickly as possible.

In Task 2, the children completed a tone-counting task, which consisted of 9 to 15 identical tones that were presented and separated by silent intervals. The goal was to silently count the tones as if they were keeping score and then provide the total count at the end. This task required children to respond under conditions of low environmental support. Therefore, the task lacked interest or reward.

In Task 3, the children completed both Tasks 1 and 2 simultaneously by seeking target shapes while concurrently counting tones.

This study was replicated with children diagnosed with ADHD. Results indicated that children with ADHD performed similar to the control group on Task 1, but performed much worse than the control group on both Task 2 and Task 3.

*Source: Adapted from T. Manly, V. Anderson, I. Nimmo-Smith, A. Turner, P. Watson, and I. H. Robertson. "The differential assessment of children's attention: The test of everyday attention for children (TEA-Ch), normative sample and ADHD performance." © 2001 by Cambridge University Press.*

#### 22) What type of attention does Task 1 measure?

- A. Divided attention
- B. Sustained attention
- C. Selective attention
- D. Executive attention

Answer: C

Foundational Concept: 6

Content Category: 6B

Skill: 1

**23) In Task 3, the children completed two tasks simultaneously, one presented in a visual modality and one in an auditory modality. If instead, two tasks were presented in the same sensory modality, performance would be expected to be:**

- A. better than when the tasks were presented in different modalities.
- B. equivalent to when the tasks were presented in different modalities.
- C. worse than when the tasks were presented in different modalities.
- D. unpredictable as performance cannot be predicted based on the given information.

Answer: C

Foundational Concept: 6

Content Category: 6B

Skill: 2

**24) Difficulties with attention and response regulation that were exhibited by the children with ADHD would be most closely linked with which of the following brain regions?**

- A. Frontal lobe
- B. Temporal lobe
- C. Parietal lobe
- D. Occipital lobe

Answer: A

Foundational Concept: 7

Content Category: 7A

Skill: 1

**25) Based on the findings described in the study, which conclusion about children with ADHD is best supported? Children diagnosed with ADHD:**

- A. perform poorly on all facets of attention.
- B. have a lower intellectual level than control, non-ADHD children.
- C. perform more poorly in school than control, non-ADHD children.
- D. show a deficit when maintaining their attention during a tedious activity.

Answer: D

Foundational Concept: 7

Content Category: 7A

Skill: 2

**26) A subgroup of children in the control group completed the same tasks two weeks after their initial testing session. Comparing their performance to that at the initial testing session would provide evidence of the task's:**

- A. reliability.
- B. reportability.
- C. standardization.
- D. validity.

Answer: A

Foundational Concept: 6

Content Category: 6B

Skill: 3

**Sample Questions 27-31** (these questions are not associated with passages)

**27) A teacher rewards his students by distributing plastic chips. Students receive a chip for each instance of good behavior. At the end of each month, they can exchange their chips for prizes. The teacher sees major decreases in bad behavior as a result of this system, which is known as:**

- A. aversive conditioning.
- B. operant extinction.
- C. a token economy.
- D. an unconditioned stimulus.

Answer: C

Foundational Concept: 7

Content Category: 7C

Skill: 1

**28) A researcher is interested in memory of novel words. He shows participants unrelated words printed on a card, one after the other. Participants see 20 words in total, wait for 2 minutes, and then are asked to write down all of the words they can remember.**

**The researcher finds that 95% of the subjects remember the first three words. This finding is an example of:**

- A. recency effect.
- B. proactive interference.
- C. the primacy effect.
- D. retroactive interference.

Answer: C

Foundational Concept: 6

Content Category: 6B

Skill: 1

**29) Researchers conducted an experiment to study Weber’s law. Going from 10- to 12-pound weights created the just noticeable difference for one participant. For this participant, how many pounds need to be added to a 20-pound weight to create the just noticeable difference?**

- A. 1 pound
- B. 2 pounds
- C. 4 pounds
- D. 8 pounds

Answer: C

Foundational Concept: 6

Content Category: 6A

Skill: 2

**30) Anxious about a nagging illness, a patient feels ignored by a doctor who is struggling to catch up with patient examinations on a very busy day. Conversely, the doctor misinterprets the discomfort and agitation of the patient as hostility. This scenario is most closely related to which paradigm?**

- A. Functionalism
- B. Conflict Theory
- C. Symbolic Interactionism
- D. Social Constructionism

Answer: C

Foundational Concept: 9

Content Category: 9A

Skill: 1

**31) Which social change is most likely to result in the greatest upward mobility?**

- A. Industrialization and the corresponding decline of subsistence agriculture
- B. Deindustrialization and the corresponding decline of manufacturing
- C. Suburbanization and the corresponding decline of urban communities
- D. Urbanization and the corresponding decline of rural communities

Answer: A

Foundational Concept: 10

Content Category: 10A

Skill: 2

## Chapter 7: What will the *Critical Analysis and Reasoning Skills* Section Test?

The *Critical Analysis and Reasoning Skills* (CARS) section of the MCAT<sup>2015</sup> exam will be similar to many of the reading tests you have taken in your academic career—it includes passages and questions that test your ability to comprehend what you read. But you may find the CARS section to be unique in several ways because it has been developed specifically to measure the analysis and reasoning skills you will need to be successful in medical school. The CARS section achieves this goal by asking you to read and think about passages from a wide range of disciplines in the social sciences and humanities, followed by a series of questions that lead you through the process of comprehending, analyzing, and reasoning about the material you have read.

CARS passages are relatively short, typically between 500 and 600 words, but they are complex, often thought-provoking pieces of writing with sophisticated vocabulary and at times intricate writing styles. Everything you need to know to answer test questions is in the passages and the questions themselves. No additional coursework or specific knowledge is required to do well on the CARS section, but you, as the test taker, may find yourself needing to read the passages and questions in ways that are different from the reading required in the textbooks used in most pre-med courses or on tests like the SAT Critical Reading. CARS passages—even those written in a conversational or opinionated style—are often multifaceted and focus on the relationships between ideas or theories. The questions associated with the passages will require you to assess the content, but you will also need to consider an author’s intentions, tones, and the words they have employed to express their points of view.

### Why does the MCAT exam include social studies and humanities passages?

CARS passages are excerpted from authentic materials found in the kinds of books, journals, and magazines that college students are likely to read. Passages from the social science and humanities disciplines might present interpretations, implications, or applications of historical accounts, theories, observations, or trends of human society as a whole, of specific population groups, or of countries. For example, a passage might discuss how basic psychological and sociological assumptions help scholars reconstruct patterns of prehistoric civilizations from ancient artifacts. Humanities passages might describe the ways art reflects historical or social change or how the philosophy of ethics has adapted to prevailing technological changes.

### What kinds of reading does the CARS section require?

All passages in the CARS section of the MCAT<sup>2015</sup> exam consist of multiple paragraphs and require thoughtful reading. As you read, it’s important to grasp the meaning of each paragraph and also to identify the relationships across all the paragraphs. Additionally, you will need to attend to the author’s stated and unstated assumptions and to the rhetorical choices he or she has made to develop stance, voice, and style. The CARS section includes ten passages followed by five to seven questions for a total of 60 questions. As such, while thoughtful reading is very important for your success, it is also important to do so quickly and efficiently.

The questions following the passages require their own focused kinds of reading, analyzing, and reasoning because many ask test takers to think about the passages from different perspectives or to

question the author’s statements, judge the relevance of the author’s examples, or consider crucial facts that might challenge the author’s assertions.

The CARS section assesses three broad critical analysis and reasoning skills. They will ask you to develop overall meaning of the text and summarize it, evaluate, and critique the “big picture,” and finally synthesize, adapt, and reinterpret concepts previously processed and analyzed. The questions following CARS passages lead test takers through this complex mental exercise of finding meaning within each text and then reasoning beyond the text to expand the initial meaning. The analysis and reasoning skills describe how mature test takers make sense of complex materials. The reading skills assessed on the CARS section are shown in Exhibit 1, and each skill is explained in the following sections.

### Exhibit 1. CARS Skills

#### Foundations of Comprehension

- Understanding the basic components of the text
- Inferring meaning from rhetorical devices, word choice, and text structure

#### Reasoning Within the Text

- Integrating different components of the text to increase comprehension

#### Reasoning Beyond the Text

- Applying or extrapolating ideas from the passage to new contexts
- Assessing the impact of introducing new factors, information, or conditions to ideas from the passage

### Foundations of Comprehension

The topics of some passages in the CARS section will be familiar topics; some will be less familiar. Explanations, illustrative examples, and definitions of significant specialized terms in these passages will help you develop the strong basic foundation needed for answering *all the questions* you encounter in this section of the MCAT<sup>2015</sup> exam.

Additionally, some questions may ask you about the overall meaning of information in the passages or the author’s central themes or ideas; others may require you to select the definitions of specific words or phrases as they are used in context. These kinds of questions help you shape the foundation that will

allow you to think in new ways about concepts or facts presented in the passages. Paragraph numbers may be included in questions to help you locate these small, relevant portions of the text.

Two sets of reading skills are the basis of the *Foundations of Comprehension* questions on the CARS section.

### ***Understanding the Basic Components of the Text***

The most fundamental questions on the CARS section ask about the basic components of the passages. Comprehension questions at this level may ask you to provide a general overview of the passage or to focus on specific portions of the text. You may be asked to identify the author’s thesis, the main point or theme of the passage, examples, or something slightly more complex, such as portions of the passage where the author digresses from the central theme.

In responding to these questions, you need to be able to recognize the purpose of different portions of the target passage: what is the thesis statement, what examples support the main idea, what statements pose an argument or assumption? An author distinguishes sections of text that indicate the existence of a sustained train-of-thought, as opposed to an isolated detail, with rhetorical labels such as “for example,” “therefore,” or “consequently.”

You will also need to be able to recognize when an author seems to have drawn upon multiple sources to support a thesis or presents different points-of-view in the single passage. It is also important to attend to perspective: does the author present her own perspective or does s/he use verbatim quotations or restatements from the perspective of other sources?

### ***Inferring Meaning from Rhetorical Devices, Word Choice, and Text Structure***

Questions may also require you to infer meanings that cannot be determined from a superficial reading of the text, such as meanings that the author has implied but did not state directly. You may have to determine how the author has structured the text—for example, through cause-and-effect relationships for scientific discussions, chronologically for historical discussions, or point-and-counterpoint for political science pieces. Identifying the structure should assist you in understanding the passage and determining its purpose, but doing so requires you to understand how the parts of a text fit together via these different kinds of relationships.

You may also need to attend to specific subtle and nuanced rhetorical decisions an author has made to shape his or her ideas, arguments, or discussions, and perhaps to complicate a passage’s meaning. For example, questions may ask you to explain paradoxes, a highlighted word or phrase, or an unexpected transition in ideas. To answer these questions, look for clues in the context around the specific sections of the passage. You may be asked to identify points of view, other than the author’s, presented indirectly through authorial summaries or paraphrases. An author’s choice about tone (e.g., humorous, authoritative, satirical) also contribute to—or obscure—meaning; and tone can often communicate the purpose for which a passage is written (e.g., to persuade, instruct, inform, entertain). For example, a satirical piece may at first seem merely entertaining, but a closer examination often reveals that its purpose is actually to persuade.

Some questions at this level may ask about information not specifically stated in the passage, and you must make assumptions based on what the author merely hints at through his or her use of connotative language or figures of speech. Look for the author’s expressed point of view and the extent to which s/he uses summaries or paraphrases to introduce others’ points of view.



The ending of passages is also fair game for questions at this level. Does the passage have a definitive solution, a partial resolution, or a call for additional research? Does it end with a dramatic rhetorical statement or a joke that leaves unanswered questions? Again, considering these questions requires one to understand how the different parts of the passage fit together to support the central thesis of the author.

### Reasoning Within the Text

Questions that test *Reasoning Within the Text* differ from those assessing *Foundations of Comprehension* in that they ask you to integrate separate passage components into a more generalized and complex interpretation of passage meaning. Questions assessing *Reasoning Within the Text* will direct your attention to an argument, claim, or theme presented in the passage and then ask you to judge the passage according to any of many criteria. The criteria could be the logic and plausibility of the passage text, the soundness of its arguments, the reasonableness of its conclusions, the appropriateness of its generalizations, or the credibility of the author and the sources he or she cites. The questions require you to dig beneath the passage's surface as you examine evidence, biases, faulty notions of causality, and irrelevant information and to determine the significance of and relationships among different parts of a passage. Additionally, some questions may require that you analyze the author's language, stance, and purpose. For example, plausible-sounding, transitional phrases may in fact be tricky. If read quickly, the words appear to make a legitimate connection between parts of a passage; however, when subjected to scrutiny, the links they appear to have established may fall apart.

This may sound like a long list of possible critical and analytical skills to have mastered, but they are in fact skills you probably already possess and use every day. Similar to your reactions when you hear someone trying to convince you about something, persuade you to a particular way of thinking, or sell you something, these questions often invite you to doubt and then judge the author's intentions and credibility. Questioning an author is a legitimate and often necessary reading strategy that can serve test takers well when making sense of complex text. Answering these questions requires looking beyond contradictions or omission of facts or details to find clues such as vague or evasive terms or language that sounds self-aggrandizing, overblown, or otherwise suspect within the context of the passage. Credible sources—essayists, scientists, lecturers, even pundits—should be both authoritative and objective and should clearly demonstrate expertise. Blatant, one-sided arguments and rigid points-of-view are easy to identify, but some authors are more nuanced in presenting biased ideas in the guise of objectivity. The key to identifying bias lies in identifying the author's *treatment* of ideas, which you achieve by analyzing and evaluating different aspects of the passage. For example, an author who uses demeaning stereotypes or derogatory labels is not likely to be a source of objective, judicious analysis.

It's important to remember that *Reasoning Within the Text* questions do not ask you to provide your own personal opinion. You may, in fact, disagree with the author's overall conclusion yet find the conclusion to be a reasonable inference from the limited information provided in the passage. If you happen to know some obscure fact or anecdote outside of the scope of the passage that could invalidate the author's conclusion, ignore it. The content of the passage or new information introduced by the questions should be the only sources from which you should base your responses. Achieving a good score on the CARS depends on this!

### Reasoning Beyond the Text

The final category, *Reasoning Beyond the Text*, requires you to use one of two critical and analytical skills, which in a way can be thought of as two sides of a single coin. Questions assessing the first set of

skills ask you to *apply or extrapolate* information or ideas presented in the passage to new or novel situations, for example, extending information presented by the author beyond the actual content of the passage.

The second set of skills involves considering new information presented in a test question, mentally *integrating* this new information into the passage content, and then *assessing* the potential impact of introducing the new elements into the actual passage. Reasoning about new, hypothetical elements should cause you to synthesize passage content anew and alter your interpretation of the passage in some plausible way.

Application and integration questions elicit some of the same kinds of thinking. Both types deal with changes caused by combinations or comparisons, and both test your mental flexibility. They do differ, however, and their distinct requirements are explained in more detail below. Remember, though, that as with questions assessing different levels of analysis and reasoning, you must still use only the content of the passages and the new information in the questions to determine your answers. Keep avoiding the temptation to bring your existing knowledge to bear in answering these questions.

### ***Applying or Extrapolating Ideas from the Passage to New Contexts***

Virtually all questions assessing application or extrapolation skills ask you how the information or ideas presented in the passage could be extended to other areas or fields. This is the kind of high-level analysis and reasoning skill scientists or theoreticians use when they consider a set of facts or beliefs and create new knowledge by combining the “givens” in new ways. Of course, these combinations may or may not result in a successful combination or outcome.

For each application item, the passage material is the “given,” and the test question provides specific directions about how the passage information might be applied to a new situation or how it might be used to solve a problem outside the specific context of the passage. As the test taker, your first task is to analyze the choices offered in the four response options so that you can gauge the likely outcome of applying existing passage content to the specified new context. Each response option will yield a different result, but each test question has only one defensible and demonstrably-correct response option.

The correct answer is the one option that presents the most likely and most reasonable outcome, based only on the information provided in the passage and question. The questions do not assess your personal ability to apply information or solve problems, only your ability to apply information from the question to the passage you have read. For example, if a question asks you to determine the author’s likely response to four hypothetical situations, you would choose the response most consistent with what the author has already said or done according to the text of the passage. In determining the correct response, rule out the options that do not fit or are incongruent with the context (e.g., framework, perspective, scenario) created by the passage material.

### ***Assessing the Impact of Incorporating New Factors, Information, or Conditions to Ideas from the Passage***

The essential difference between application and incorporation skills is that the two-part purpose of incorporation questions is to introduce a specific piece of information for you to consider and to ask you to assess how ideas in the passage might be affected by its introduction. The premise of these questions

is that ideas and information in the passages are potentially malleable, not a fixed framework, as in application questions.

In some incorporation questions, you must find the best answer to a “what if” question by re-interpreting and re-assessing passage content with the additional fact or idea introduced by the question. Does the new information support or contradict the inherent logic of the passage? Could the new information co-exist with what is already in the passage, or would it negate an aspect of the author's argument? If the latter is the case, the question could ask what modifications or alterations might need to be made to the passage content to accommodate the new element introduced by the question. Remember, the passage should be considered malleable.

Other forms of incorporation questions may ask you to think about a possible logical relationship that might exist between the passage content and the facts or assertions included in the answer options. The task is to select the one option that, if added to the passage content, would result in the *least* amount of change. The correct response option will present the situation or argument that is most similar to what is outlined in the passage. In other words, you must determine which new fact or assertion could be added to the passage with the least amount of alteration to the central thesis that the passage has developed.

Some other incorporation questions are based on analogies. Analogical reasoning assumes that any two things known to be alike in some way must be alike in other ways as well. Here, likeness is measured not by inherent similarity but by analogy. Questions of this type assess your skill at identifying a fundamental common feature shared by seemingly-different concepts or assumptions and then determining which of the response options parallels an approach to a problem that is central to the passage. Comparing how the response options relate to one another might also help you to identify the relevant point of correspondence. Just remember that with these questions you will need to look below any surface imagery to identify underlying relationships, processes, or paradigms. The correct response option is the one that could be easily integrated into the malleable conceptual framework of the passage. The skill required here is much like that required to integrate new scientific findings into an already existing body of knowledge.

## Passage Content

*Critical Analysis and Reasoning Skills* passages come from a variety of humanities and social sciences disciplines.

### Humanities

Passages in the humanities are drawn from a variety of disciplines; including:

- Architecture
- Art
- Dance
- Ethics
- Literature
- Music
- Philosophy
- Popular Culture
- Religion
- Theater

Passages may describe the ways art reflects historical or social change, or how the philosophy of ethics has adapted to prevailing technological changes. Often focusing on the relationships between ideas, humanities passages are more likely to be written in a conversational or opinionated style. Therefore, you should keep in mind the tone and word choice of the author in addition to the passage assertions themselves.

### Social Sciences

Social science passages are also drawn from a variety of disciplines; including:

- Anthropology
- Archaeology
- Cultural Studies
- Economics
- Education
- Geography
- History
- Linguistics
- Political Science
- Population Health
- Psychology
- Sociology

Passages from the social science disciplines tend to center on the interpretations, implications, or applications of historical accounts, theories, observations, or trends of human society as a whole, of specific population groups, or of countries. They may also be multifaceted. For example, you might be provided with a passage about how basic psychological and sociological assumptions help scholars reconstruct patterns of prehistoric civilizations from ancient artifacts.

## **Distribution of Questions by Critical Analysis and Reasoning Skill and Passages by Content Domain**

You may wonder how many questions you'll get testing a particular critical analysis and reasoning skill, or how many humanities and social science passages you'll see on the test. For each test form, you are likely to see questions and passages distributed in the ways described below.

### **Critical Analysis and Reasoning Skill:**

- Foundations of Comprehension: 30%
- Reasoning Within the Text: 30%
- Reasoning Beyond the Text: 40%

### **Passage Content:**

- Humanities: 50%
- Social Sciences: 50%

As we continue developing this test section, these percentages may be adjusted. Additional detail about any adjustments to this section will be posted on the MCAT<sup>2015</sup> website as soon as it is available.

## Sample Test Questions<sup>20</sup>: *Critical Analysis and Reasoning Skills*

Sample test questions for the *Critical Analysis and Reasoning Skills* section are provided below. The answer key appears below each question, along with the skill the question is testing. These sample questions will give you an idea of what to expect from this section of the exam.

### Sample Passage 1 (from Population Health): Questions 1–5

Rudolph Virchow, the nineteenth-century German physician, came of age with two dramatic events — a typhoid outbreak in 1847, and the failed revolutions of 1848. Virchow gained two insights from those experiences: 1) the spread of disease has much to do with appalling living conditions; and 2) those in power have enormous means to subjugate the powerless. As Virchow summarized in his famous epigram, “Physicians are the natural attorneys of the poor.”

Physicians are advocates for the underprivileged because poverty and poor health tend to go hand in hand. Poverty means bad or insufficient food, unhealthy living conditions, and endless other factors leading to illness. When you examine socioeconomic status (SES) — a composite measure that includes income, occupation, education, and housing conditions — it becomes clear that, starting with the wealthiest stratum of society, every step downward in SES correlates with poorer health.

This “SES gradient” has been documented throughout Westernized societies as the impetus for a variety of health problems. It is not a subtle statistical phenomenon. When you compare the highest versus the lowest rungs of the SES ladder, the risk of some disease varies tenfold.

So what causes this correlation between SES and health? Lower SES may give rise to poorer health, but conversely, poorer health could also give rise to lower SES. After all, chronic illness can compromise one’s education and work productivity, in addition to generating enormous expenses.

Nevertheless, the bulk of the facts suggests that the arrow goes from economic status to health — that SES at some point in life predicts health measures later on. Among the many demonstrations of this point is a remarkable study of elderly nuns in the U.S. All had taken their vows as young adults and had spent many years thereafter sharing diet, health care, and housing, thereby controlling for those lifestyle factors. Yet in their old age, patterns of disease, incidence of dementia, and longevity were still significantly predicted by their SES status from when they became nuns, at least half a century before.

So how does SES influence health? The answers that seem most obvious, it turns out, do not hold much water. One such explanation posits that for the poor, health care may be less easily accessible and of lower quality. But that explanation fails for reasons made clearest in the famed Whitehall studies. These studies documented an array of dramatic SES gradients in a conveniently stratified population, namely, the members of the British civil service (ranging from blue-collar workers to high-powered executives). Office messengers, for example, have far higher mortality rates from chronic heart disease than professionals do. Lack of access to medical attention cannot explain the phenomenon, because the U.K. has universal health care.

The next “obvious” explanation centers on unhealthy lifestyles. As you descend the SES ladder in Westernized societies, people are more likely to drink excessively or smoke. They are also less likely to

<sup>20</sup> These sample passages and questions have not followed the same review and field-test procedures as do operational test materials.

have access to clean water and healthy food. Thus, it seems self-evident that lower SES affects health by increasing risks and decreasing protective factors.

What is surprising, though, is how little of the SES gradient these risk and protective factors explain. It is reasonable to assume that the wealthier a country, the more financial resources its citizens have to buy protection and avoid risk. If so, health should improve incrementally as one moves up the wealth gradient among nations, as well as among the citizens within individual nations. But it does not. Instead, among the wealthiest quarter of countries on earth, there is no relation between a country's wealth and the health of its people.

*Source: Adapted from R. Sapolsky, "Sick of poverty." ©2005 Scientific American, Inc.*

- 1) Which of the following facts presented in the passage provides the greatest support for the claim that unhealthy lifestyles do NOT have a substantial effect on the SES gradient?**
- A. As one descends the SES ladder in Westernized societies, people are more likely to smoke or drink excessively.
  - B. Lower SES affects health by increasing risks and decreasing protective factors.
  - C. The wealthier a country, the more financial resources its citizens have to buy protection and avoid risk.
  - D. Among the wealthiest quarter of countries on earth, there is no relation between a country's wealth and the health of its people.

Answer: D

Skill: Reasoning Within the Text

- 2) Based on information in the passage, with which of the following statements about the health of people in the U.S. would the passage author be most likely to agree?**
- A. People in the U.S. who are on the lower rungs of the SES ladder are more likely to drink excessively or smoke than people on the higher rungs.
  - B. People in the U.S. who are on the lower rungs of the SES ladder have just as easily accessible and equal quality health care as do people on the higher rungs.
  - C. People in the U.S. are less likely to have insufficient food or unhealthy living conditions than people in other Westernized societies.
  - D. People in the U.S. who are on the highest rungs of the SES ladder generally have better health than similarly situated people in slightly less wealthy Westernized countries.

Answer: A

Skill: Reasoning Beyond the Text

**3) Which of the following study findings would provide the greatest support for the claim that poorer health leads to lower SES?**

- A. Children who are born into families lower on the SES ladder are significantly more likely to have poorer health later in life.
- B. Children who are born into families lower on the SES ladder are significantly more likely to be hospitalized more than twice during their first two years of life.
- C. Children who are hospitalized more than twice during their first two years of life are significantly more likely to have a lower income later in life.
- D. Children who are hospitalized more than twice during their first two years of life are significantly more likely to have poorer health later in life.

Answer: C

Skill: Reasoning Beyond the Text

**4) Which of the following would provide a “conveniently stratified population” most similar to the population examined in the Whitehall studies?**

- A. Members of a university faculty
- B. Members of a military branch
- C. Members of a monastery
- D. Members of a state legislature

Answer: B

Skill: Reasoning Beyond the Text

**5) Based on the discussion in the fifth paragraph, the fact that the nuns shared lifestyle factors for the past fifty years was most helpful because it enabled researchers to:**

- A. predict the nuns’ future patterns of disease, incidence of dementia, and longevity.
- B. calculate the nuns’ SES status at the time of the study.
- C. determine that the variability in the nuns’ health in their old age was predicted by their SES status when they were young.
- D. learn which component of the nuns’ SES status contributed the most to their longevity.

Answer: C

Skill: Foundations of Comprehension



**Sample Passage 2 (from Cultural Studies): Questions 6–11**

In Indian society, as I see it, there's a constant struggle between two distinct attitudes toward life: the spiritualism of the renunciatory *Vedanta philosophy* and its opposite, the materialistic, hedonistic *charvakas*. It can be seen in the stark white simplicity of the ankle-white cloth worn by men versus the richly colored silk sari of the Indian woman; the culinary asceticism of the vegetarian versus the complexity of the most varied and subtle cuisine on earth; the tradition of non-violent resistance versus the militarism of a nuclear power with the fourth largest army on earth.

The most basic duality of all is that between India and *Bharat*, which is the name of the country in Hindi. India has shot satellites into space and boasts a business capital with the highest commercial rents in the world. It has had the most rapid televisual growth of any country on earth. But *Bharat* (the indigenous India that speaks Hindi) lives in village huts, plows fields, and has no phones.

*Bharat* is winning over India in the naming game—re-naming cities and landmarks to wipe away vestiges of past British rule. Forbidding the use of the name *Bombay* for any official purposes, officials of one state have renamed their capital *Mumbai*. This strikes me as the equivalent of a well-known brand jettisoning its name in favor of a new, obscure one. *Bombay*, which comes from the Portuguese term for “good bay,” has already entered the global discourse (in *Bombay gin* and *The Bombay Company* furniture) and enjoys name recognition that many cities in the world would pay millions to acquire. *Madras* was renamed *Chennai*, despite the famous cloth that bears its name. Yet it turned out *Chennai* was the name of an English colonial governor and *Madras* had an impeccably Indian pedigree.

So bad history is worse lexicography, but in India-that-is-*Bharat* it can prove to be good politics. What's in a name, Shakespeare asked? Are we Indians so insecure in our freedom that we need to prove to ourselves that we are free? Is it necessary to confer a new name on cities in the same way that, in parts of the country, it is customary for a bride to take on a new surname and first name—chosen by her husband's family?

In today's India, billboards offering Western goods are striking testimony to the globalization of Indian life. In the past, national self-respect seemed to require that we make everything we needed here, however badly. But one of the lessons of history is that you can learn the wrong lesson from history.

We used to be unfriendly to foreign investors. But not today. Those few people who offered violent resistance in a bid to close down Kentucky Fried Chicken outlets in India might consider that Indian farmers profit by selling their chickens to KFC at dollar-inspired rates. Those Indians who object to call centers for multinational information technology companies are like the buggy-whip manufacturers who protested the invention of the automobile, because it would deprive them of work.

We will not become any less Indian if our country lets foreign winds blow through our house. The strength of “Indianess” has always consisted in its ability to absorb foreign influences and to transform them into something that belongs on Indian soil. The language in which this book is being published in India is just one example of this. We can drink Coca-Cola or write in English without becoming colonized.

*Source: Adapted from S. Tharoor, “India: From midnight to the millennium.” ©2000 Shashi Tharoor.*

**6) Based on paragraph one, would believers in the Vedanta philosophy consider themselves part of Bharat or India?**

- A. Bharat, because it is depicted as a simple, earthy existence.
- B. Bharat, because it is the place where Hindi is spoken.
- C. India, because it comprises a real, international political entity.
- D. India, because spiritual progress depends on basic material goods.

Answer: A

Skill: Reasoning Within the Text

**7) According to the passage, those people who comprise Bharat would be most likely:**

- A. to realize the fact that the origins of Chennai are English.
- B. to protest the existence of Kentucky Fried Chicken outlets.
- C. to market Bombay gin and Bombay Company furniture.
- D. to support the wearing of very colorful saris.

Answer: B

Skill: Reasoning Beyond the Text

**8) According to the passage, the linguistic origins of names:**

- A. are not always able to be determined definitively.
- B. can be misconstrued because of cultural enthusiasms.
- C. can cast doubt on the truth of a nation's history.
- D. are sometimes literally descriptive of a country.

Answer: B

Skill: Foundations of Comprehension

**9) Which one of the following statements, if assumed to be true, would add the most support to the passage author's point in the next-to-the-last sentence of the passage?**

- A. Indians who speak English adopt British pronunciation.
- B. Indians regard Hindi as their common language.
- C. English is taught as an elective in Indian schools.
- D. English is one of India's many official languages.

Answer: D

Skill: Reasoning Beyond the Text

**10) The passage makes it clear that the author is:**

- A. an Indian writing for an audience of Indians.
- B. a spokesperson for multinational industry.
- C. partial to the point of view of Vendanta philosophers.
- D. a foreigner writing to an audience of foreigners.

Answer: A

Skill: Reasoning Within the Text

**11) The “wrong lesson” that India learned from its past history, according information the passage author provides, is:**

- A. capitulation to colonial power.
- B. capitulation to progress.
- C. passive resistance to colonialism.
- D. resistance to foreign culture and commerce.

Answer: D

Skill: Foundations of Comprehension

### Sample Passage 3 (from Ethics): Questions 12–17

A predetermined covenant of confidentiality characterizes the physician-patient relationship. Possession of contraband in prison is illegal. But suppose that during a routine medical examination, a prison physician notices that Prisoner A has drugs and paraphernalia. Should the physician report the crime, or should confidentiality prevail?

Professional communications between physicians and patients are statutorily protected as confidential. A routine physical examination is part of the confidential communication, like information obtained by taking a medical history and data entered in the patient’s health record. Health professionals have an interest in maintaining confidentiality so that patients will feel comfortable in revealing personal but necessary information. Prisoners do not possess full Constitutional rights to privacy, but they generally retain rights to privacy when there is a special relationship between communicants, such as the physician-patient relationship. In fact, respect for confidentiality is particularly important in a prison hospital setting, in which patients feel distrust because physicians are often employed by the incarcerating institution.

Clinical autonomy for health professionals in the prison setting is essential for good medical practice. Physicians working in prisons also retain the privilege of confidential interactions with patients, although the prison authorities may try to pressure doctors to supply information. Even if physicians are employed by the prison, their first responsibility is to their patients. The circumstances in which to give privileged information to prison authorities remains the physician’s decision.

The finding that contraband detected during an examination has the appearance of drugs and paraphernalia, like all results of the examination, is privileged information to be treated confidentially. The right to privacy supersedes a duty to report the discovery because there is no imminent threat to others. In contrast, a weapon harbored by a prisoner represents an imminent threat to other prisoners and to prison staff. Thus, upon discovering a sequestered weapon during the course of a routine examination, the physician has a “duty to warn.” According to case law, when the physician believes that a significant threat of harm exists, the duty to warn takes precedence over the patient’s right to privacy.

The case of Prisoner A raises the issue of the point at which to draw the line between the duty to protect the public and the duty to protect patients’ privacy. Although legal guidelines can assist the physician in making the choice, the health professional must rely on a guiding principle of the medical profession: Where no danger to others exists, patients come first.

The possibility of discovering contraband during routine examinations of prisoner patients reinforces the need for informed consent at several stages. First, prisoner patients should be evaluated and treated only after they provide informed consent, unless they are incompetent. Before an X-ray is taken, they should be informed that it can demonstrate metal and other foreign bodies, and their agreement to the procedure should be obtained. Second, if a concealed weapon is discovered during a routine examination, the prisoner patient should be informed that the discovery will be reported and given the opportunity to surrender the weapon to authorities before more forcible means are taken to remove it. If Prisoner A is harboring drugs and a needle, drug use is quite possibly contributing to A’s health problem. It is the physician’s responsibility to educate A about the potential harm of drug use.

*Source: Material used in this test passage has been adapted from the following source: C. Levine (Ed.), Cases in Bioethics: Selections from the Hastings Center Report. ©1989 St. Martin’s Press.*

**12) Assume that a prison did not have a policy of obtaining informed consent before a diagnostic procedure, and almost all of the inmates refused to be X-rayed. The author's comments suggest that this situation could reasonably be interpreted as evidence that prisoners:**

- A. believe that they have a Constitutional right to privacy.
- B. are less concerned about their health than are nonprisoners.
- C. distrust physicians who are employed by the prison.
- D. feel a need to carry weapons for self-protection.

Answer: C

Skill: Reasoning Beyond the Text

**13) Suppose that a prisoner under sedation for a medical procedure inadvertently reveals that a weapon is hidden in the prisoner's cell. Passage information suggests that the author would be most likely to advise the physician to report the incident:**

- A. only if the prisoner threatened to use the weapon.
- B. only if the prisoner consented to the report.
- C. only if the prisoner subsequently denied that the weapon existed.
- D. regardless of the patient's assertions.

Answer: D

Skill: Reasoning Beyond the Text

**14) The author argues that a routine examination is part of the confidential communication between a patient and a physician and that the clinical autonomy of the physician is essential for good medical practice in prisons. These beliefs imply that:**

- A. if the quality of medicine practiced in a prison declines, a physician has violated the confidentiality of a routine examination.
- B. if all physicians in a prison refuse to reveal information about prisoners obtained during routine examinations, the physicians in that prison have clinical autonomy.
- C. if all physicians who conduct routine examinations in a prison respect their patients' confidence, the quality of medicine practiced in the prison is high.
- D. if a physician is required to reveal information about a prisoner obtained during a routine examination, the quality of medicine practiced in the prison suffers.

Answer: D

Skill: Reasoning Within the Text

**15) With respect to prisoners, “necessary information” (paragraph 2) probably refers most specifically to a patient’s:**

- A. past criminal activities.
- B. use of illegal drugs.
- C. intent to harm others.
- D. psychiatric history.

Answer: B

Skill: Foundations of Comprehension

**16) Which of the following conclusions about physician confidentiality can be inferred from the passage?**

- A. It is more likely to be assumed in a private setting than in a prison.
- B. It is especially important when patients are incompetent to give informed consent.
- C. It is threatened by the use of invasive diagnostic tools such as X-rays.
- D. It is an aspect of a Constitutional right that is lost by prisoners.

Answer: A

Skill: Foundations of Comprehension

**17) Which of the following objections, if valid, would most *weaken* the argument made for the special importance of the physician-patient covenant within prisons?**

- A. Prisoners understand that X-rays will detect hidden weapons.
- B. Prisoners assume that physicians are independent of the institution.
- C. Prison officials often question physicians about prisoners.
- D. Prisoners often misunderstand their Constitutional rights.

Answer: B

Skill: Reasoning Beyond the Text

### Sample Passage 4 (from Literature): Questions 18–22

Author of the famous five-part Leatherstocking series, twenty-seven other novels, and a box of historical and miscellaneous works, James Fenimore Cooper remains one of the most innovative yet most misunderstood figures in the history of U.S. culture. Almost single-handedly in the 1820s, Cooper invented the key forms of U.S. fiction — the Western, the sea tale, the Revolutionary romance — forms that set a suggestive agenda for subsequent writers, even for Hollywood and television. In producing and shrewdly marketing fully 10 percent of all U.S. novels in the 1820s, most of them best-sellers, Cooper made it possible for other aspiring authors to earn a living by their writings. Cooper can be said to have invented not just an assortment of literary genres but the very career of the U.S. writer.

Despite Cooper’s importance, he continues to be profoundly misunderstood, and this is partly his own fault. Although it was becoming common for writers in the early nineteenth century to indulge public curiosity about their lives, the usually chatty Cooper turned reticent when asked for biographical details. Whereas contemporaries, such as Sir Walter Scott and Washington Irving, made prior arrangements for authorized biographies, Cooper refused to follow suit. When nearing death in 1851, he insisted that his wife and children protect his life and his papers from outsiders. His private documents remained out of reach to most scholars until the 1990s.

The biographical problem is only one reason for Cooper’s languishing reputation. Another reason is that he’s always been the object of strong feelings, pro and con. Almost from the start of his career, Cooper was admired, imitated, recited, and memorized. In his day, he was reportedly the author most widely translated into German, and what has been called “Coopermania” hit France especially hard as early as the 1820s. Yet, from the outset, he was also subjected to various criticisms that, when combined with later politically motivated assaults, have hampered true appreciation of his work. Critics have at times faulted him for his occasional bad grammar, his leisurely pacing, and his general inability to eclipse his greatest contemporary, Sir Walter Scott.

The criticisms were not without merit. But the problems in Cooper’s first books need to be understood in their proper context. At least some of Cooper’s failings were owing to the very newness of what he was attempting. Robert E. Spiller summed up this point in 1931 by noting that Cooper “always suffered from the crudities of the experimenter.”

Cooper was not just a path breaking figure in the history of writing in the U.S., or a potent visionary; he was a remarkably representative man. He was as much at home in the salons of New York City or the country houses of the rural Hudson Valley as in the raw frontier villages where his family’s life had taken its root and rise. Knowing the country’s most characteristic landscapes in ways that few of his contemporaries did, Cooper wrote of them with unexampled authority. He closely followed the War of 1812, partly because his friends fought in it, and partly because so much hinged on its outcome. Cooper thereafter joined in the effort of his most influential contemporaries to forge a new culture for the reaffirmed nation. One might say that Cooper’s story is almost incidentally a literary story. It is first a story of how, in literature and a hundred other activities, Americans during this period sought to solidify their political and cultural and economic independence from Great Britain and, as the Revolutionary generation died, stipulate what the maturing Republic was to become.

*Source: Adapted from W. Franklin, in defense of Cooper. ©2007 by W. Franklin.*

**18) Which of the following best describes an assumption made by the passage author in the first paragraph?**

- A. Ten percent of all U.S. novels produced in the 1820s were best sellers.
- B. The most innovative figures in U.S. culture are often the most misunderstood.
- C. Before the 1820s, U.S. writers were unable to earn a living by their writings.
- D. Cooper was the only U.S. author writing during the 1820s.

Answer: C

Skill: Foundations of Comprehension

**19) Which of the following statements about authors is most strongly implied by information in the second paragraph?**

- A. The public is most curious about authors who are reticent when asked about their lives.
- B. Authors who authorize biographies of themselves are likely to be better understood than authors who do not.
- C. Authors did not share biographical details of their lives before the early nineteenth century.
- D. Most authors' papers are not protected from outsiders after the authors die.

Answer: B

Skill: Foundations of Comprehension

**20) Which of the following people would the passage author most likely consider to be remarkably representative, as this concept is used in the final paragraph?**

- A. Someone who has written many stories set in various locations
- B. Someone who has an understanding of a variety of diverse locations
- C. Someone who is well liked by people from different backgrounds
- D. Someone who has written descriptions of many famous landscapes

Answer: B

Skill: Reasoning Beyond the Text



**21) Which of the following situations in the automotive industry is the most analogous to the one described in the fourth paragraph regarding Cooper’s early writings?**

- A. An automobile manufacturer introduces a new model that quickly becomes the best-selling vehicle in its class.
- B. An automobile manufacturer designs a vehicle that becomes popular with a group of people different from the group the manufacturer had anticipated.
- C. An automobile manufacturer has unexpected mechanical issues with an innovative new vehicle after its release.
- D. An automobile manufacturer offers an extended warranty on its vehicles in an attempt to shed its reputation for poor craftsmanship.

Answer: C

Skill: Reasoning Beyond the Text

**22) Which of the following passage assertions is the LEAST supported by examples or explanations in the passage?**

- A. “Cooper can be said to have invented not just an assortment of literary genres but the very career of the U.S. writer.”
- B. “[Cooper] continues to be profoundly misunderstood, and this is partly his own fault.”
- C. “Cooper was not just a path breaking figure in the history of writing in the U.S. ... he was a remarkably representative man.”
- D. “[Cooper] closely followed the War of 1812, partly because his friends fought in it, and partly because so much hinged on its outcome.”

Answer: D

Skill: Reasoning Within the Text

## Chapter 8: What Preparation Products and Services are Available?

### Products and Services to Help You Prepare

The AAMC offers you a combination of low-cost and free test preparation materials and services for the MCAT<sup>2015</sup> exam. In 2014, a full-length practice test and *The Official Guide to the MCAT<sup>2015</sup> Exam* will be released. A second full-length practice test will be released in 2015.

The AAMC website includes a section dedicated to the new exam. The site has an electronic version of the *Preview Guide for the MCAT<sup>2015</sup> Exam* and other resources to help you to learn more about the new exam, including information about test preparation materials, answers to frequently asked questions, and details about the review process leading up to the new exam. Also on the website are short informational videos, including one that features a medical student and a resident talking about the new exam and their personal experiences preparing for and taking the current MCAT exam.

Be sure to check out the website for new updates and information about the MCAT<sup>2015</sup> exam by visiting [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

In 2014, the AAMC will release a free, full-length practice test. The online practice test will mirror the actual exam and provide you with an opportunity to practice with both the interface and functionality of the exam. It will allow you to practice with test questions just like those that will be on the actual exam. You will have several options for taking the test, including one that delivers the exam under timed conditions. Upon completion of the practice test, a report summarizing results will be displayed. You will also have the option to go back and review the test questions and their solutions.

Also in 2014, *The Official Guide to the MCAT<sup>2015</sup> Exam* will be released. Similar to the current guidebook, *The Official Guide to the MCAT<sup>®</sup> Exam*, the new guidebook will provide an overview of all the information needed to help ensure a positive MCAT experience. *The Official Guide to the MCAT<sup>2015</sup> Exam* will be organized into two sections. The first section of the new guidebook will provide an overview of “everything MCAT,” including information about the registration process, what to expect on test day, important information about the exam itself, and how scores are used in the admissions process. The second section of the new guidebook will provide an overview of the exam content. It also will include a set of practice questions for every section of the new exam, along with detailed solutions and tips for getting the right answers.

In 2015, a second full-length practice test will be available. This test also will provide the option to simulate actual testing conditions or to choose selected questions from the test for more targeted practice. And, as with all practice tests, it will include a detailed score report and the opportunity to review the solutions for every test item.

Please visit the AAMC website to stay up-to-date with all of the latest MCAT<sup>2015</sup> test preparation products and services the AAMC offers: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

## Products and Services to Support Pre-health Advisors and Other Baccalaureate Faculty

The AAMC is committed to working with pre-health advisors, other baccalaureate faculty, and medical school admissions officers to ensure that all students have opportunities to succeed on the new exam. In support of this goal, the AAMC delivered MCAT<sup>2015</sup> informational presentations, developed MCAT<sup>2015</sup> outreach materials and the Course-Mapping Tool for the MCAT<sup>2015</sup> Exam, and launched the Pre-health iCollaborative project. These initiatives will help ensure that students master the necessary knowledge and skills prior to sitting for the exam, enable them to identify the undergraduate courses that provide them opportunities to develop these skills, and lastly, learn which methods of instruction best target exam concepts.

- **MCAT<sup>2015</sup> Outreach Materials**

The AAMC has a variety of outreach materials and tools available to help pre-health advisors and other faculty to discuss the MCAT<sup>2015</sup> exam with their colleagues and students. These include online videos about the exam, downloadable handouts and presentation materials. For questions about these materials, e-mail [mcat2015@aamc.org](mailto:mcat2015@aamc.org).

- **Course-Mapping Tool for the MCAT<sup>2015</sup> Exam**

The courses needed to prepare for the MCAT<sup>2015</sup> exam differ by school. In order to help faculty, advisors, and students identify the courses on their campuses that teach the knowledge and skills needed for the MCAT<sup>2015</sup> exam, the AAMC, with input from pre-health advisors, has developed a tool that can be used to match MCAT<sup>2015</sup> content to courses. The tool prompts users to match MCAT<sup>2015</sup> content to courses, so that advisors, faculty, and students can see the different combinations of courses that help students acquire the knowledge and skills tested on the exam.

- **Pre-health iCollaborative - [www.mededportal.org/icollaborative/pre-health](http://www.mededportal.org/icollaborative/pre-health)**

In order to help undergraduate faculty find instructional resources for teaching pre-health competencies and preparing students for medical school, AAMC has launched the Pre-health iCollaborative, a free repository of instructional resources. Faculty who want to share instructional resources with colleagues can make them available through this repository. Faculty can also find instructional resources they can incorporate in their own curriculum by searching by MCAT<sup>2015</sup> foundational concepts. The collection is further enhanced by user comments on each resource. Pre-health iCollaborative also offers independent study resources students can use to supplement their coursework.

As they develop, more details will be provided about these projects and updates for pre-health advisors and other baccalaureate faculty at: [www.aamc.org/mcat2015/admins](http://www.aamc.org/mcat2015/admins).

## Chapter 9: Where can Additional Information about the MCAT<sup>2015</sup> Exam be Found?

You can find more information about the MCAT<sup>2015</sup> exam at the following websites.

- For prospective examinees: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015)
- For pre-health advisors and other baccalaureate faculty: [www.aamc.org/mcat2015/admins](http://www.aamc.org/mcat2015/admins)
- For medical schools admissions officers and faculty: [www.aamc.org/mcat2015/admins](http://www.aamc.org/mcat2015/admins)

Information about the activities and data that shaped its design appears at:

- Medical School Survey Report: [www.aamc.org/mcat2015/msnsreport.pdf](http://www.aamc.org/mcat2015/msnsreport.pdf)
- Undergraduate Natural Sciences Survey Report: [www.aamc.org/mcat2015/ugnsreport.pdf](http://www.aamc.org/mcat2015/ugnsreport.pdf)

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