

**MCAT**  
Medical College  
Admission Test



# MCAT 2015

A Better Test for Tomorrow's Doctors

**Preview Guide  
for MCAT 2015**  
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MCAT® is a program of the  
Association of American Medical Colleges

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This is the first draft of the Preview Guide to MCAT<sup>2015</sup>. We will improve it in response to readers' questions and comments. Please see the MCAT<sup>2015</sup> website [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015) for updates.

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## Introduction

The *Preview Guide for MCAT<sup>2015</sup>* is a blueprint for the exam that will be introduced in 2015. The *Preview Guide* 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 examinees and others prepare for MCAT<sup>2015</sup>.

While the *Preview Guide for MCAT<sup>2015</sup>* is written for prospective MCAT examinees, 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 students 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 MCAT<sup>2015</sup>* 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 examinees prepare?
- What products and services are available for pre-health advisors and other baccalaureate faculty?
- Where can additional information about MCAT<sup>2015</sup> 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 MCAT<sup>2015</sup>, 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>1</sup>

What is different and exciting about the new exam?

- The natural sciences sections of MCAT<sup>2015</sup> 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.
- MCAT<sup>2015</sup> 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 is also new. This 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, cross-cultural studies and population health are included.

<sup>1</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 MCAT<sup>2015</sup>, 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 MCAT<sup>2015</sup> Measure?

MCAT<sup>2015</sup> 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 to solve problems that demonstrate your readiness for medical school.

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; and
- 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 using knowledge of social and behavioral sciences concepts.

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

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

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



Table 1: Summary of MCAT <sup>2015</sup>	Approximate number of items	Approximate number of minutes
<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>	65	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 human 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>	65	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 psychological 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>	65	95
<p><b><i>Critical Analysis and Reasoning Skills</i></b></p> <p>This section asks you to critically analyze, evaluate, and apply 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, cross-cultural studies, and population health.</p>	60	90

## Chapter 3: How will MCAT<sup>2015</sup> 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*.)

The two natural sciences tests 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 MCAT<sup>2015</sup> are based on the recommendations from this research.<sup>2</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 MCAT<sup>2015</sup> and the *Psychological, Social and Behavioral Foundations of Behavior* section test ten foundational concepts in all:<sup>3</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 Biological Foundations of Behavior* section is organized around foundational concepts 6-10.

<sup>2</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>3</sup> Foundational concepts 1-3 mirror entering medical student competencies 5-7 described by the Scientific Foundations for Future Physicians Committee. Foundational concepts 4 and 5 mirror entering medical student competencies 3 and 4. Foundational concept 1 includes the ideas from entering medical student competency 8.

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 multicellular organisms
- 2B. 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:** *Biological, psychological, and socio-cultural factors influence how 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:** *Social and cultural 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 affects access to resources and well-being.*

The content category for this foundational concept includes:

- 10A. Social inequality

## Scientific Inquiry and Reasoning Skills<sup>4</sup>

Four scientific inquiry and reasoning skills are tested on the natural, social and behavioral sciences sections. They are:

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

The following paragraphs describe the scientific inquiry and reasoning skills targeted by the new exam.

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

Skill 1 focuses on your ability to recognize, recall, define, relate and apply fundamental concepts and principles specified in the natural and social sciences in order to derive answers — something natural and social scientists do every day in their work. It is through a solid understanding of the scientific concepts and principles that explain natural phenomena, and the ability to recognize conditions of application that answers are found.

Your ability to use mathematics and data displays to find the answers while in the process of working with scientific concepts and principles is also assessed. Demonstrating these abilities may require the use and interpretation of information provided in a variety of forms, such as words, pictures, graphs, tables, formulas, and diagrams.

To demonstrate this skill, you should be able to:

- state or recognize correct science concepts and principles;
- recognize relationships among closely-related scientific concepts and principles;
- recognize relationships among different representations of concepts and principles;
- use mathematical representations of concepts and principles; and
- recognize graphical or schematic representations of concepts and principles.

Note: This is a partial list for illustrative purposes; it is not exhaustive.

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<sup>4</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.

## **Skill 2: *Scientific Reasoning and Evidence-based Problem Solving***

Natural and social scientists use scientific principles, models, and theories to describe and explain natural phenomena, make predictions about those phenomena, and develop new research questions. Scientific principles, models, and theories can come in variety of forms including words, pictures, graphs, tables, formulas, and diagrams.

Scientists also use knowledge of principles, models, and theories to reason about interconnections among natural phenomena, evaluate arguments and explanations of causes and consequences, and draw evidence-based conclusions. They also use integrated theories in combination with evidence to solve problems and broaden scientific knowledge and understanding.

Evidence-based reasoning is used by scientists to test and refine their theories and models. It is important that they recognize the importance of considering multiple scientific perspectives, arguments, and sources of evidence when working to solve a problem. Before drawing a conclusion, scientists identify key assumptions and evaluate evidence relative to their claim. This is considered a critical part of the validation process.

To demonstrate this skill, you should be able to:

- work with scientific models and theories to solve problems;
- make claims and propose research questions or hypotheses based on scientific theories and models;
- identify assumptions and logical inconsistencies in arguments to evaluate a conclusion;
- propose and/or evaluate alternative explanations or predictions;
- work with the stated conclusions from a research study to solve problems;
- identify and apply appropriate formulas to solve problems within a given context; and
- use and evaluate proposed solutions.

Note: This is a partial list for illustrative purposes; it is not exhaustive

### **Skill 3: Reasoning about the Design and Execution of Research**

Scientists differ in many ways — from the phenomena they study to how they do their work. However, all scientists have one thing in common: they all engage in the design and execution of research.

Natural and social scientists test scientific questions using quantitative and qualitative research methods. This means that both experimental and non-experimental designs are drawn upon to gather data and test hypotheses. Scientists develop research designs in order to define the variables they need to examine. When designing and conducting research, scientists adhere to ethical guidelines designed to protect the rights of research participants, the integrity of the work, and the interests of research consumers.

Data collection is done in ways that allow scientists to measure associations between variables, test causal relationships between variables, or make predictions about them. Sampling is one method of data collection in which scientists sometimes engage.

Sampling is the act of selecting a subset of individual units from a target population, and using information gathered about the subset to draw conclusions about the target population as a whole.

To demonstrate this skill, you should be able to:

- identify foundational aspects of research design (e.g., experimental vs. non-experimental design, independent and dependent variables);
- identify the appropriate research designs needed to address specific research questions or hypotheses;
- critique different aspects of a research design (e.g., identify sources of potential bias, confounds, adequacy of sample);
- evaluate research designs to determine if conclusions based on the research study are appropriate;
- recognize ethical issues inherent in research investigations; and
- make predictions about expected results based on the features of a research design.

Note: This is a partial list for illustrative purposes; it is not exhaustive.



## **Skill 4: *Data-based and Statistical Reasoning***

Natural and social scientists use data-based and statistical reasoning to: describe and explain phenomena in the natural world, explain relationships between variables, test hypotheses, and solve problems. Data-based reasoning allows for an understanding of interconnections among natural phenomena, evaluation of evidence for scientific theories, drawing evidence-based conclusions, and refinement or extension of existing scientific knowledge.

Scientists describe and analyze the research data they collect using a variety of descriptive statistics. These may include frequency distributions, measures of central tendency and dispersion, and graphical representations of the relationships among variables, such as scatter plots and measures of association.

Inferential statistics are used to test whether existing data patterns from research samples generalize to named populations. Scientists use significance tests to judge the certainty of inferences about differences between samples and populations.

Natural and social scientists must be able to read and interpret results using tables, graphs, and charts. This is a necessary skill that allows for conclusions to be reached and arguments to be made based on the evidence.

To demonstrate this skill, you should be able to:

- use data to describe phenomena in the natural world and/or to describe results of a research study;
- use descriptive statistics to summarize data (e.g., mean, median, and standard deviation) and relate it to the population (e.g., standard error);
- interpret data or patterns in data to draw conclusions or evaluate the conclusions made at the end of a research study (e.g., notice whether conclusions logically follow based on the data presented);
- interpret data, or patterns in data, to make predictions;
- use statistics to answer research questions and evaluate the strength of the evidence provided in support of given hypotheses; and
- interpret data patterns presented in tables, figures, and graphs (e.g., histograms, scatterplots) to interpret results, make comparisons, and draw conclusions.

Note: This is a partial list for illustrative purposes; it is not exhaustive.

## 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.**

	Foundational Concept 1			Foundational Concept 2		
	Content Category 1A	Content Category 1B	Content Category 1C	Content Category 2A	Content Category 2B	Content Category 2C
Skill 1						
Skill 2						
Skill 3						
Skill 4						

Each cell represents the point at which foundational concepts, content categories, and scientific inquiry and reasoning skills cross.

Test questions are written at the intersections of the knowledge and skills.

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:** How the organ systems interact (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

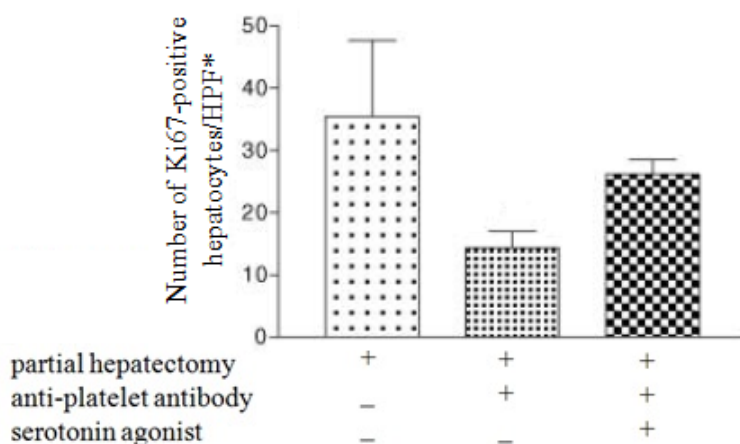
## Sample Passage<sup>5</sup>

In many animals, including mice and humans, the liver quickly regenerates to its original size after a partial hepatectomy, which is when 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 percent 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 percent 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).

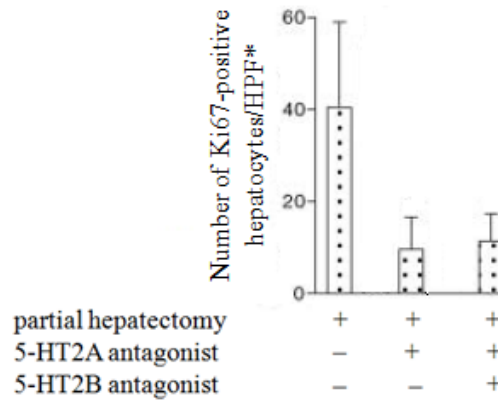


**Figure 1.** Effects of platelet depletion and serotonin agonist on hepatocyte proliferation (\*HPF = high power field).

<sup>5</sup> This sample passage and question have not followed the same review and field-test procedures as do operational test materials.

### Experiment 2

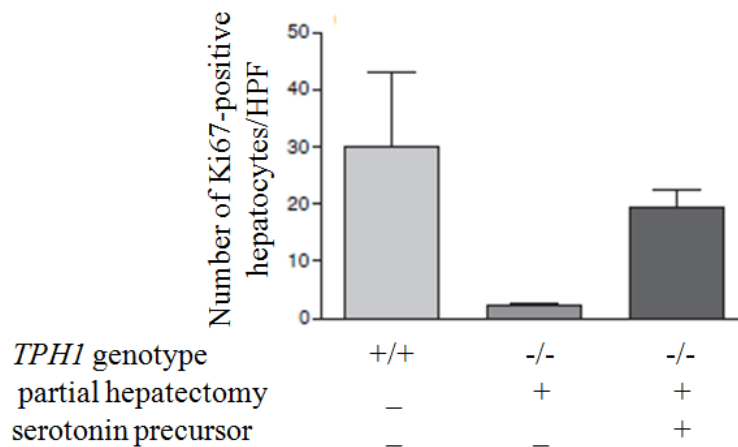
Wild-type mice were treated with antagonists of the serotonin receptors 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub>, receptors that are expressed on hepatocytes and other cells types (Figure 2).



**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 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?
- A. Administration of 5-HT<sub>2A</sub> receptor agonist resulted in reduced Ki67 staining.
  - B. RNA for seven different receptor subtypes was detectable 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.

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.

## 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. Here is an excerpt from the content list.

#### **EXAMPLE**

- Fatty Acid Catabolism (BIO, BC)** ← **Topic**
- General
  - Digestion/mobilization/transport ← **Subtopic**
  - Oxidation
    - Saturated fats
    - Unsaturated fats
  - Ketone bodies
  - Net molecular and energetic results of respiration processes
  - 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 “Fatty Acid Catabolism” at the level at which it is taught in a typical two-semester introductory biology sequence AND 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.

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**

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 living 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 living 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, and how the synthesis and degradation of macromolecules functions to maintain health, and about the various forms of biochemical dysfunction that 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)



## **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 (respiratory)
- Immune system
- Motors (muscle)
- Voltage sensitive membrane channels (BIO)

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

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

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

- Kinetics
  - General (catalysis)
  - Michaelis-Menten
  - Cooperativity
- Inhibition – types
  - Feedback
  - Competitive
  - Non-competitive
- Regulatory enzymes
  - Allosteric enzymes
  - Covalently-modified enzymes
  - Zymog

## **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, and amplify them, and to analyze and identify unknown 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)**

- 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 that are 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' chromosomes 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:

### **DNA Structure and Function (BIO)**

- Evidence that DNA is genetic material

### **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

## 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 *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)

- Bioenergetics/thermodynamics
  - Free energy/ $K_{eq}$
  - Concentration
- 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
- Pentose phosphate pathway



- Net molecular and energetic results of respiration processes

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

- Regulation of metabolism
  - Dynamic steady state

### **Glucose and Glycogen (BC)**

- Regulation: glycolysis/gluconeogenesis
- Regulation of glycogen synthesis
- Analysis of metabolic control
  - Allosteric and hormonal control

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

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

### **Fatty Acid Catabolism (BIO, BC)**

- General
- Digestion/mobilization/ transport
- Oxidation
  - Saturated fats
  - Unsaturated fats
- Ketone bodies
- Net molecular and energetic results of respiration processes
- Anabolism of fats (BIO)
- Non-template synthesis: biosynthesis of lipids and polysaccharides (BIO)
- Metabolism of proteins (BIO)

## ***Biological and Biochemical Foundations of Living Systems***

### **Foundational Concept 2**

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 for not only 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 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.

## **Category 2A: Assemblies of molecules, cells, and groups of cells within 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 and mechanisms of molecules, or groups of molecules, by which they move across cell membranes. How cell–cell junctions and the extracellular matrix interact to form tissues with specialized functions, epithelial tissue, and connective tissue are also covered in this category. (Nervous tissue and muscle tissue are covered in Foundational Concept 7, Content Categories A and B.). 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
  - 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
- Nervous tissue (covered in Foundational Concept 7, Content Category A)
- Muscle tissue (covered in Foundational Concept 7, Content Category B)

## **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**

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, 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, nervous, 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.

### **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 (OC)

### **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

### **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

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

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 circulatory, respiratory, digestive, lymphatic, excretory, reproductive, immune, muscle, and skeletal 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
- Antigen presentation
- Clonal selection
- Antigen-antibody recognition
- Concept of antigen and antibody
- 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
- Contraction
  - 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

## Distribution of Questions by Foundational Concept and Discipline

You may wonder how much chemistry you'll see on the test. 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 items you may see on a test form for each foundational concept and related discipline.

### Foundational Concept:

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

### Science Discipline:

- First-semester biochemistry : 25%
- Introductory biology: 65%
- General chemistry: 5%
- Organic chemistry: 5%

As we continue developing this test section, the weights 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>6</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 a list of the foundation concept, content category, and skill it targets.

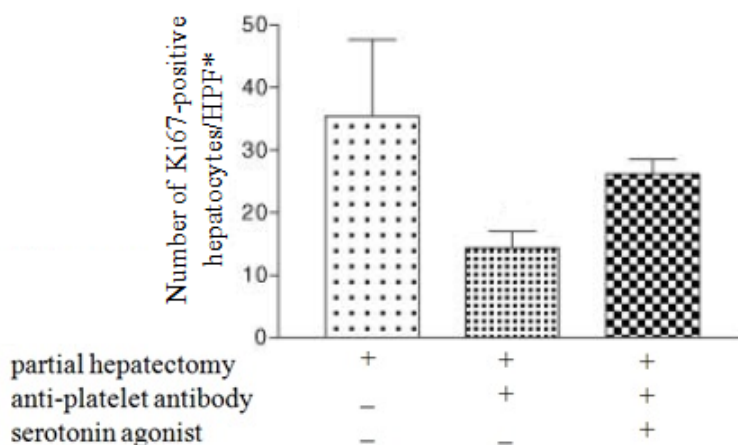
### Sample Passage 1: Questions 1–5

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 percent 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 percent 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).

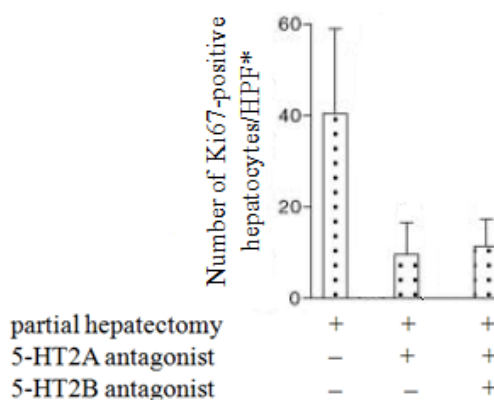


**Figure 1.** Effects of platelet depletion and serotonin agonist on hepatocyte proliferation (\*HPF = high power field)

<sup>6</sup> These sample passages and questions have not followed the same review and field-test procedures as do operational test materials.

### Experiment 2

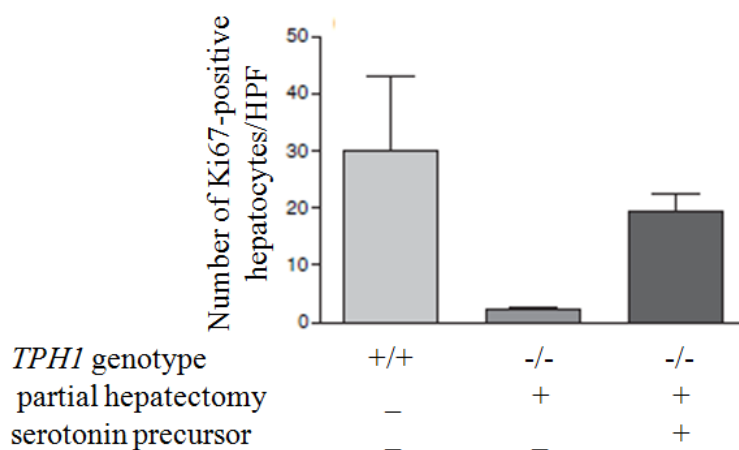
Wild-type mice were treated with antagonists of the serotonin receptors 5-HT<sub>2A</sub> and 5-HT<sub>2B</sub>, receptors that are expressed on hepatocytes and other cell types (Figure 2).



**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.

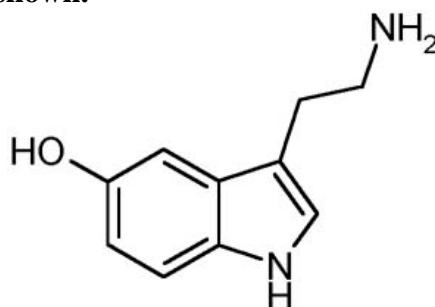
Answer: D

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-HT2A and 5-HT2B receptor subtypes mediate serotonin-dependent liver regeneration?**

- A. Administration of 5-HT2A 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-HT2A and 5-HT2B was observed during periods of peak hepatocyte proliferation.
- D. Administration of 5-HT2C and 5-HT3 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

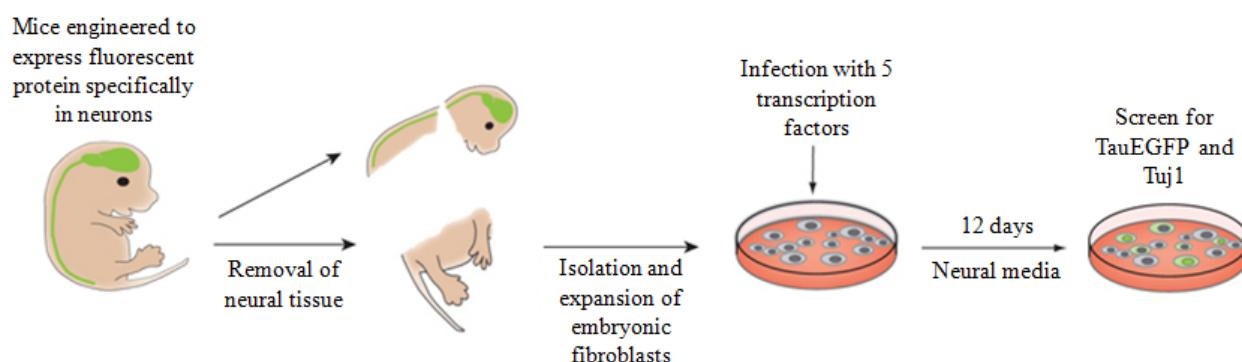
Content Category: 1A

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.

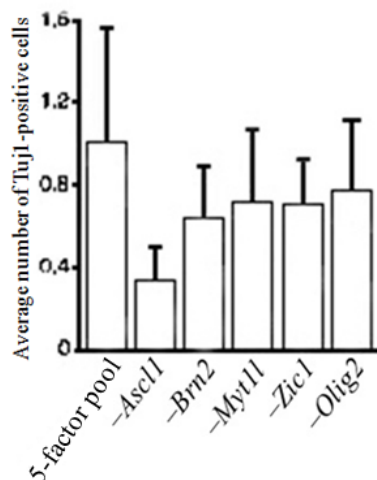
Scientists set out to test whether neural-lineage-specific transcription factors could convert embryonic fibroblasts from TauEGFP mice, mice engineered to express a green fluorescent protein in their neuronal tissues only, into neurons using the protocol shown in Figure 1.



**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 examine 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: 2D

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: 3B

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. High molecular weight and increased number of epitopes
- B. High molecular weight and reduced number of epitopes
- C. Low molecular weight and increased number of epitopes
- D. Low 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* test 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. Here is an excerpt from the content lists.

#### **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
- 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” 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**

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 the human body follow the laws of physics. They can be quantified, in fact, 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, 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)

## **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

### **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.

### **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



## **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 into 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 vs. 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 mol/L
- Ideal gas
  - definition
  - Ideal Gas Law: Boyle's Law
  - Ideal Gas Law: Charles' Law
  - Ideal Gas Law: Avogadro's Law
- Kinetic Molecular Theory of Gases
  - Heat capacity at constant volume and at constant pressure
  - Boltzmann's Constant
- 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 Spectra (OC, GC)**

- Absorption spectroscopy

- Infrared region (OC)
  - Intramolecular vibrations and rotations
  - Recognizing common characteristic group absorptions, fingerprint region
- Visible region
  - Absorption in visible region gives complementary color (e.g., carotene)
  - Effect of structural changes on absorption (e.g., indicators)
- Ultraviolet region (OC)
  - $\pi$ -electron and non-bonding electron transitions
  - Conjugated systems
- NMR spectroscopy (OC)
  - 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
- Ground state, excited states
- Absorption and emission line spectra
- Use of Pauli Exclusion Principle
- Paramagnetism and diamagnetism
- Conventional notation for electronic structure
- Bohr atom
- Heisenberg Uncertainty Principle
- Effective nuclear charge
- Photoelectric effect

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

- Electronic structure
- 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)**

- Electronic structure
  - The representative elements
  - The noble gases
  - Transition metals
- 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

## *Chemical and Physical Foundations of Biological Systems*

### **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 chemical processes that take place within the human body 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.



## 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, OC)

- 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, OC)

- 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
- 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)**

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

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

- 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

## Lipids (BC, OC)

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

## 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
- Keto-enol tautomerism of monosaccharides
- Disaccharides
- Polysaccharides

## Aldehydes and Ketones (OC)

- Description
  - Nomenclature
  - Physical properties
  - Infrared absorption of C=O bond, spectroscopy
- Important reactions
  - Nucleophilic addition reactions at C=O bond
    - Acetal, hemiacetal
    - Imine, enamine
    - Grignard reagents
    - Cyanohydrin
  - Oxidation of aldehydes
  - Reactions at adjacent positions: enolate chemistry
    - Keto-enol tautomerism ( $\alpha$ -racemization)
    - Aldol condensation, retro-aldol
    - Lithium enolates
    - 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)
  - Infrared absorption of OH group: spectroscopy
- Important reactions
  - Oxidation
  - Pinacol rearrangement in polyhydroxyalcohols; synthetic uses
  - Protection of alcohols
  - Preparation of mesylates and tosylates

## Carboxylic Acids (OC)

- Description
  - Nomenclature
  - Physical properties and solubility; acidity: carboxylate stability through resonance
    - Infrared absorption
- 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
  - Infrared absorption
- 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 thermo-dynamics 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)**

- Mechanism
  - Substrates and enzyme specificity
  - Active site model
  - Induced-fit model
  - Co-enzymes 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 LeChatelier’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 the test. 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 items you'll see on your test forms for each foundational concept and discipline.

### Foundational Concept

- 4: 40%
- 5: 60%

### Science Discipline

- First-semester biochemistry: 15%
- Introductory biology: 5%
- General chemistry: 30%
- Organic chemistry: 25%
- Introductory physics: 25%

As we continue developing this test section, the weights 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 Items<sup>7</sup>: *Chemical and Physical Foundations of Biological Systems*

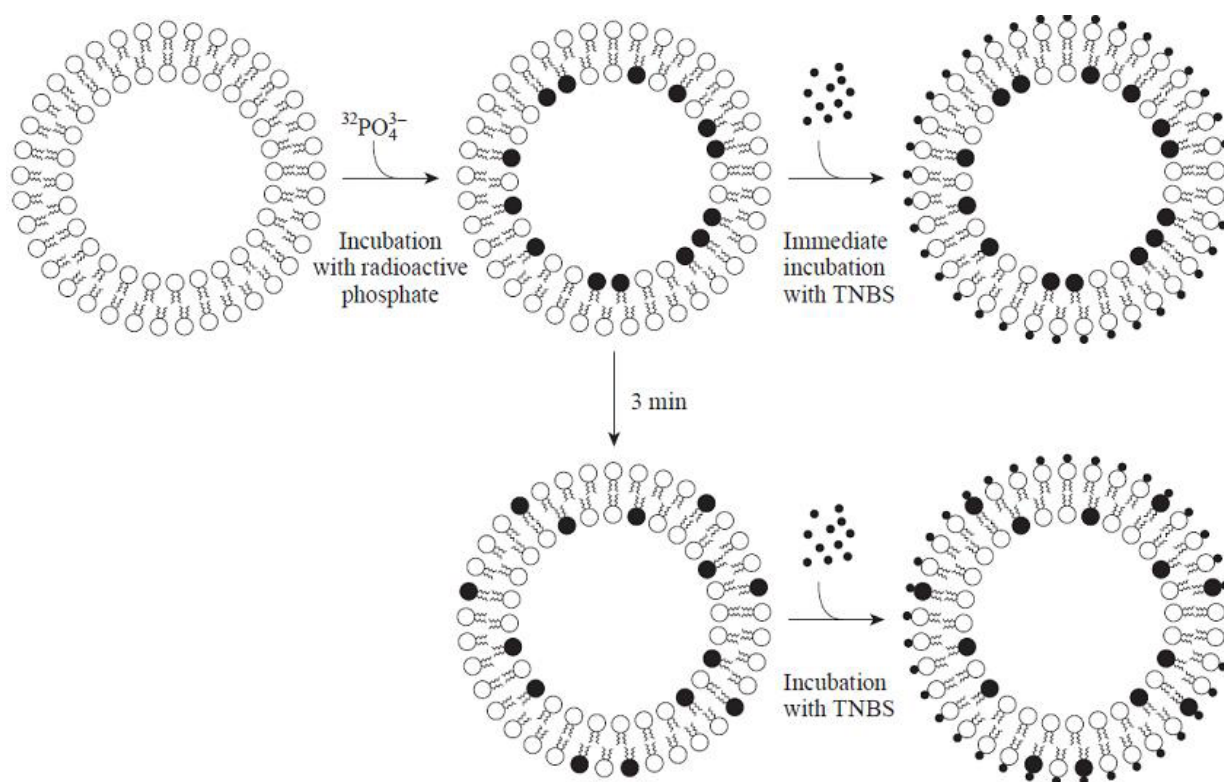
Sample test questions for the *Chemical and Physical Foundations of Biological Systems* test are provided below. The answer keys appear below the questions, along with the skills the questions are testing. These sample questions will give you an idea of what to expect from this section of the exam.

### 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  $^{32}\text{P}$ -labeled phosphate ( $^{32}\text{PO}_4^{3-}$ ) in an effort to identify the location of PE synthesis. In this experiment newly synthesized PE will contain a  $^{32}\text{P}$  label. When growing bacteria are treated with a pulse of radioactive  $^{32}\text{PO}_4^{3-}$  followed by immediate treatment with TNBS, almost none of the TNBS-labeled PE contained  $^{32}\text{P}$ . In contrast, if an interval of only three minutes was allowed to elapse between the  $^{32}\text{PO}_4^{3-}$  pulse and the TNBS treatment, almost 50% of the  $^{32}\text{P}$ -labeled PE was also TNBS labeled. These results are summarized in Figure 1.

<sup>7</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:**
- A. faster than the rate of exchange between inner and outer envelope PE molecules.
  - B. slower than the rate of phosphate transport across the membrane.
  - C. facilitated by the additional phosphate present in solution.
  - D. 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

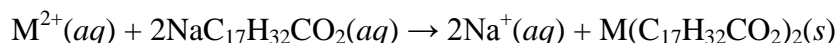
Content Category: 5D

Skill: 3

## Sample Passage 2: Questions 6–10

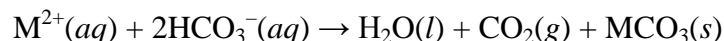
Hard water contains cations that form precipitates with soap or upon boiling. The principle hardness ions are  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{Fe}^{2+}$ . There are two major drawbacks of hard water.

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.



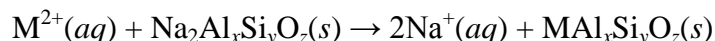
### Reaction 1

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

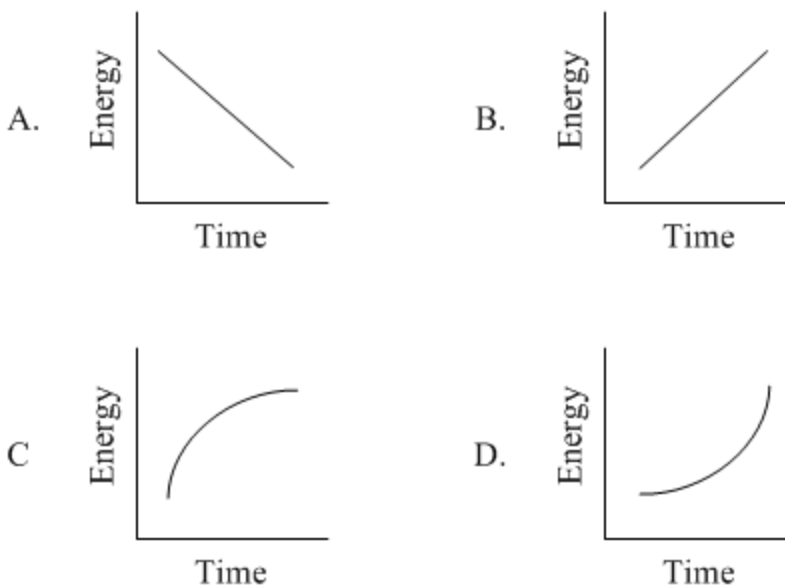
Content Category: 5D

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 Items: 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.  $7 \times 10^{12}$

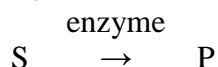
Answer: C

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  $V_0$ ?

A.

B.

C.

D.

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 Foundational of Behavior* section. As with the natural sciences sections, content lists describing specific topics and subtopics that define each content category are provided. Here is an excerpt from the content list.

#### **EXAMPLE**

##### **Self-presentation and interacting with others (PSY, SOC) ← Topic**

- Expressing and detecting emotion ← Subtopic
  - Gender influences shape expression
  - Culture influences shape expression
- Impression management (SOC)
  - Front stage vs. backstage self (Goffman)
  - Background expectancies (Garfinkel)
- Focused and unfocused interactions (SOC)
- Social rules and talk
- 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 a typical introductory sociology course.
- You are responsible for learning about the subtopics, “impression management” and “focused and unfocused interactions,” only at the levels at which they are taught in a typical sociology course.
- You are responsible for learning about the subtopic, “animal signals and communication,” only at the level at which it is taught in typical introductory psychology and biology courses.

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 responses.

#### **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 how we sense and perceive the world. All sensory processing begins with us 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 of our senses. The topics and subtopics in this category are:

### Sensory Processing (PSY, BIO)

- Sensation (PSY)
  - Thresholds
  - Signal detection theory
  - Sensory adaptation
- Sensory receptors transducer stimulus energy and transmit signals to the central nervous system
  - Sensory pathways
  - Types of sensory receptors
- The cerebral cortex controls voluntary movement and cognitive functions
  - Information processing in the cerebral cortex
  - Lateralization of cortical functions

### Vision (PSY, BIO)

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

#### 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
  - Perceiving loudness and pitch
  - Locating sounds
- Sensory reception by hair cells

## Other Senses (PSY, BIO)

- Somatosensation
  - Sensory systems in the skin
  - Tactile pathways in the brain
  - Types of pain
  - Factors that influence pain
- Taste
  - Taste buds/chemoreceptors that detect specific chemicals in the environment
  - Gustatory pathways in the brain
- Smell
  - Olfactory cells/chemoreceptors that detect specific chemicals in the environment
  - Pheromones
  - Olfactory pathways in the brain
  - Role of smell in perception of taste

## Perception (PSY, BIO)

- Bottom-up/Top-down processing
- Perceptual organization (i.e., depth, form, motion, constancy)
- Gestalt principals

## **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 this 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

### **Cognition (PSY)**

- Cognition
  - Consciousness
- Cognitive development
  - Piaget's stages of cognitive development
  - Information-processing approach
  - Cognitive changes in late adulthood
  - Role of culture in cognitive development
  - Influence of heredity and environment on cognitive development
- Biological factors that affect cognition
- Problem solving
  - Types of problem solving
  - Barriers to effective problem solving
  - Approaches to problem solving
- Factors that influence decision-making and forming judgments
  - 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 (intellectual disabilities)



## Memory (PSY)

- Encoding
  - Process of encoding information
  - Processes that aid in encoding memories
- Storage
  - Types of memory storage (i.e., sensory, short-term/working, long term)
  - Biological factors that affect the storage process
  - 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
- Changes in synaptic connections underlie memory and learning (PSY, BIO)
  - Neural plasticity
  - Memory and learning
  - Long-term potentiation (BIO)

## 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 strategies for coping with stress. The topics and subtopics in this category are:

### **Emotion (PSY)**

- Three components of emotion (i.e., cognitive, physiological, behavioral)
- Universal emotions (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 regions of the brain
  - Limbic system
  - Emotion 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 (i.e., cataclysmic events, personal, etc.)
- 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 our behavior. Biological structures and processes serve as the pathway by which our bodies carry out activities. They also affect our predisposition to behave in certain ways, shape our personalities, and influence our likelihood of developing psychological disorders. Psychological factors also affect our behavior, and consequently, our health and well-being.

The content in this category covers biological bases of behavior including genetics and how the nervous and endocrine systems affect behavior. It also addresses how personality, psychological disorders, motivation, and attitudes affect behavior. The topics and subtopics in this category are:

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

- The nervous system
  - Neurons
  - Neurotransmitters
  - Peripheral nervous system
  - Central nervous system
  - How neurons influence behavior
  - How neurotransmitters influence behavior
- The endocrine system
  - Components of the endocrine system
  - How the endocrine system affects behavior
- The brain
  - The brainstem
  - The cerebellum
  - The diencephalon
  - The cerebrum
  - How components of the brain influence behavior
- Behavioral genetics
  - Genes, temperament, heredity
  - Adaptive value of traits and behaviors
  - Interaction between heredity and environmental influences
- Both genetic makeup and environment contribute to the development of behaviors
  - Experience and behavior
  - Regulatory genes and behavior
  - Genetically based behavioral variation in natural populations

### **Personality (PSY)**

- Theories of personality
  - Psychoanalytic perspective
  - Humanistic perspective
  - Trait perspective
  - Social cognitive perspective
- The role of biology in personality

- The role of the situation in personality

## **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
- Nervous system disorders can be explained in molecular terms (PSY, BIO)
  - Schizophrenia
  - Depression
  - Drug addiction and brain reward system
  - Alzheimer's disease
  - Parkinson's disease
  - Stem cell-based therapy to regenerate neurons in CNS

## **Motivation (PSY)**

- Theories that explain how motivation affects human behavior
  - Instinct
  - Drive reduction
  - Arousal
  - Other: incentives, cognitive, and needs approaches
- 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
- Sleep and Circadian rhythms
- Influence of biological rhythms on physiological functioning
- Role of sleep in waking and non-waking behavior

## **Attitudes (PSY)**

- Components of attitudes (i.e., cognitive, affective, behavioral)
- The link between attitudes and behavior
  - Processes by which behavior influences attitudes (i.e., 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, SOC)**

- Social facilitation
- Deindividuation
- Bystander effect
- Social loafing
- Peer pressure

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

- Group polarization (PSY)
- Groupthink

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

- Assimilation
- How culture affects human behavior

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

- Definition of socialization (SOC)
- Norms
- Agents of socialization (e.g., the family, mass media, peers, workplace)
- Conformity and deviance
- Power 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, including associative, observational, and social learning.

While 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 our own 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:

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

- Classical conditioning
  - Neutral, conditioned, and unconditioned stimuli
  - Conditioned and unconditioned response
  - Processes: acquisition, extinction, spontaneous recovery, generalization, discrimination
- Operant conditioning
  - 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 (PSY, BIO)
  - Innate behaviors are developmentally fixed
  - Learned behaviors are modified based on experiences
  - Development of learned behaviors
- Applications of classical and operant conditioning to explain individual behavior

### **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 (i.e., 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.

In medical school, students will learn about interacting and collaborating with patients, their families, and 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 notion of self-concept and identity, and the role of self-esteem, self-efficacy, and locus of control in the development of our self-concept. Identity formation including developmental stages and the social factors that affect identity formation is also covered here. 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
- Different types of identities (e.g., race/ethnicity, gender, age, sexual orientation, class)

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

- Developmental stages of identity development
  - Theories of developmental stages (e.g., Erikson, Vygotsky)
- Influence of social factors on identity formation
  - Influence of individuals (i.e., imitation, role-taking)
  - Influence of group (i.e., reference group)
- Influence of culture on identity formation
- The effect of socialization on identify 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 the environment and culture affect these 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, class
  - The role of emotion in prejudice
  - The role of cognition in prejudice
- Stereotypes
- Ethnocentrism
  - In-group and out-group
  - Ethnocentrism vs. cultural relativism

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

- 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.

A variety of factors — personality, environment, culture, and our 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 interpretation including expressing and detecting emotion, impression management, focused and unfocused interactions, communication, and the biological underpinning of social behavior. The topics and subtopics in this category are:

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

- Expressing and detecting emotion
  - Gender influences shape expression
  - Culture influences shape expression
- Impression management (SOC)
  - Front stage vs. backstage self (Goffman)
  - Background expectancies (Garfinkel)
- Focused and unfocused interactions (SOC)
- Social rules and talk
- Communication
  - Animal signals and communication (PSY, BIO)

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

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

### **Discrimination (SOC)**

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

## *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 health care and are potential determinants of health care 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 health care, interactions with providers, and health outcomes.

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

Social structure organizes all human societies. Elements of social structure include agency, 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 institutions, and how and why people interact within and among these institutions. It covers the components of social structure, such as agency and institutions, theoretical paradigms, 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:

### **Components of social structure (SOC)**

- Agency
- Institutions
- Interaction between agency and institutions

### **Theoretical paradigms (SOC)**

- Functionalism
- Conflict
- Symbolic Interactionism
- Social Constructionism
- Theories of Globalization

### **Specific social institutions (SOC)**

- Education
- Family
- Religion
- Government and Economy

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

- Material culture (SOC)
- Symbolic culture
  - Values and beliefs
  - Norms and rituals
- Culture and social groups
- Evolution and human culture (SOC, 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:

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

- Statuses
- Roles (PSY, SOC)
- Groups (PSY, SOC)
- Networks

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

- Age
- Gender
- Race and ethnicity
- Sexual orientation
- Geographic distribution (SOC)
- Demographic transitions (SOC)

## *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 health care, and how these influences are potential determinants of health care outcomes. Knowledge of these concepts will prepare students to learn about the ways patients' social class and living conditions affect their access to health care, 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
  - Residential location and exposure to health risks

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

- Theories of stratification
  - Class, status, and power
  - Cultural/social capital and social reproduction
  - Privilege and prestige
- Patterns of social mobility
  - Intergenerational
  - Downward and upward mobility
  - Meritocracy
- Poverty
  - Relative and absolute
  - Culture of poverty argument
  - Social exclusion (segregation and isolation)

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

- Fertility and mortality

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

- Race, gender, and other class-based inequalities in healthcare



## Distribution of Questions by Foundational Concept and Discipline

You may wonder how much psychology, sociology, and biology you'll see on the test. 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 items you'll see on a test for each foundational concept and discipline.

### Foundational Concept:

- 6: 25%
- 7: 30%
- 8: 25%
- 9: 15%
- 10: 5%

### Discipline:

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

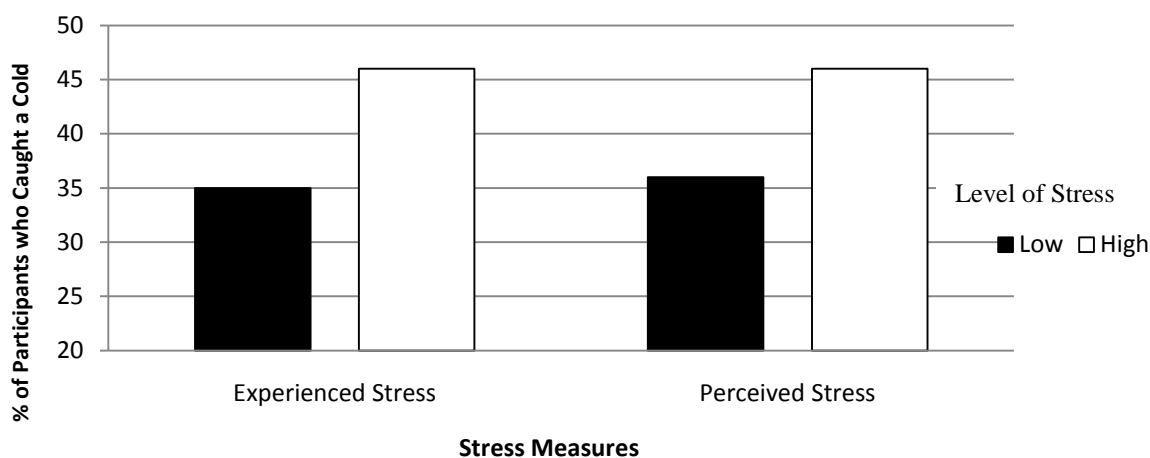
As we continue developing this test section, the weights may be adjusted. Additional detail about any adjustments to this section will be posted on the MCAT<sup>2015</sup> website as soon as it is available.

## Sample Test Items<sup>8</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 keys appear below the questions, along with the skills the questions are 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

When faced with a stressor, humans experience physiological changes including increased heart rate and blood pressure, and changes in hormone levels that affect the immune system. Physiological responses of the human body to psychological stressors, such as public speaking, resemble its responses to physical stressors, such as pain. In a study designed to examine the impact of psychological stress on the immune system, participants completed two self-report measures in order to assess experienced stress versus perceived stress. One measure obtained the number of stressful life events the participant had experienced over the last year. The second measure assessed the extent to which the participant perceived life events as stressful. After the participants gave their informed consent and the stress-related information was collected, participants were quarantined and exposed to the common cold virus and their symptoms were monitored. Figure 1 represents the findings from this study.



**Figure 1.** Rate of Developing Colds as a Function of Experienced and Perceived Stress

Additional studies have examined psychological factors that might influence the relationship between stress and the immune system. It has been demonstrated that individuals higher in optimism (optimists), are more likely than those lower in optimism to attribute their stressors to controllable causes, engage in a problem-focused coping style rather than an avoidant coping style, and have healthier lifestyles. Moreover, physiological measures have shown that optimists have lower levels of cortisol and a more responsive immune system.

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

*Sources:*

*Adapted from Cohen, S., Tyrrell, A.J., & Smith, A.P. (1993). "Negative life events, perceived stress, negative effect, and susceptibility to the common cold." Journal of Personality and Social Psychology, 46, 131-140.*

*Aspinwell, L.G., Richter, L., & Hoffman, R.R. (2001). "Understanding how optimism works: An examination of optimists' adaptive moderation of belief and behavior."*

*Chang, Edward C. (Ed.). "Optimism & pessimism: Implications for theory, research, and practice" Washington, DC, US: American Psychological Association, pp. 217-238.*

**1) Which of the following changes to the study would make it possible to investigate whether there is a causal link between stress, coping styles, and immune susceptibility?**

- A. Exposing participants to a stressor in the laboratory and collecting self-report data about perceived stress immediately after exposure.
- B. Exposing participants to a stressor in the laboratory and then collecting self-report data about perceived stress over several months.
- C. Randomly assigning participants to complete different questionnaires about their coping styles prior to exposing them to a stressor.
- D. Randomly assigning participants to conditions in which they learn different coping styles prior to exposing them to a stressor.

Answer: D

Foundational Concept: 6

Content Category: 6C

Skill: 3

**2) Which of the following results would you predict if this study were extended to examine learned helplessness? People who develop learned helplessness:**

- A. attribute their stressors to controllable causes.
- B. engage in problem-focused coping.
- C. have higher levels of cortisol.
- D. are less susceptible to immune system diseases.

Answer: C

Foundational Concept: 7

Content Category: 7C

Skill: 2

**3) Which of the following conclusions is NOT supported by Figure 1?**

- A. Experiencing stressful events is positively associated with susceptibility to the cold virus.
- B. Experiencing stressful events is negatively associated with immune functioning.
- C. Perceived stress levels are negatively associated with immune functioning.
- D. Perceived stress is positively associated with an increase in immune functioning.

Answer: D

Foundational Concept: 6

Content Category: 6C

Skill: 4

**4) Which of the following is NOT necessary for ensuring that the study described in the passage is ethical? Making sure that the:**

- A. participants fully understand the risks and the symptoms associated with the common cold virus.
- B. virus used in the study does not pose a greater risk than a cold virus the participants might be exposed to in their day to day lives.
- C. participants receive assistance in the months following the study to reduce the amount of stress in their lives.
- D. participants are compensated for the time they put into the study and any discomfort they experienced as a result.

Answer: C

Foundational Concept: 6

Content Category: 6C

Skill: 3

**5) Which division of the nervous system is directly involved in regulating the stress-related physiological changes listed in the passage?**

- A. Central nervous system
- B. Somatic nervous system
- C. Sympathetic nervous system
- D. Parasympathetic nervous system

Answer: C

Foundational Concept: 7

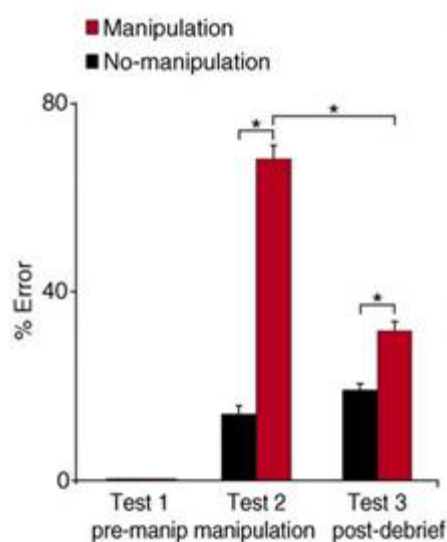
Content Category: 7A

Skill: 1

## Sample Passage 2: Questions 6-10

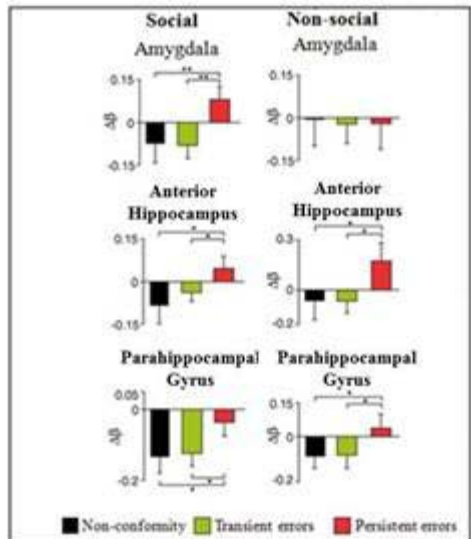
In a phenomenon known as “memory conformity,” people change their recollections of events to match the recollections of others. Memory conformity is persistent or transient. In persistent conformity, an individual’s recollection is altered, resulting in persistent memory errors. In transient conformity, individuals provide accounts consistent with that of others, but inwardly maintain belief in their original memory.

A study examined how socially induced memory errors are generated in the brain by evaluating the memory of adults exposed to false recollections of others. After viewing a documentary in a group, participants individually completed three memory tests. Test 1 assessed the accuracy of each participant’s memory before the study manipulation. Test 2 was identical to Test 1, but was administered four days later and included a social manipulation. Before responding during Test 2, participants were presented with images of their co-observers, either with false answers (manipulation) or with the letter X (no-manipulation). Test 2 was completed while participants were being scanned with functional magnetic resonance imaging (fMRI). Test 3 occurred one week later. Participants were told that the co-observers’ responses at Test 2 were random and to complete the test based on their original memories. Figure 1 presents the study’s results.



**Figure 1.** Conformity levels (\* $p < 0.002$ ).

An additional study was conducted using the same design but a different manipulation during Test 2 to a non-social manipulation. Instead of answers from co-observers, participants were told the information was generated from computer algorithms. The results for the two imaging studies are shown in Figure 2.



**Figure 2.** Blood Oxygen Level-Dependent Signals in Regions of the Medial Temporal Lobe when Additional Information is Introduced in Social and Non-Social Contexts (\* $p < 0.05$ ; \*\* $p < 0.005$ ).

Source: Adapted from Edelson, M., Sharot, T., Dolan, R., & Dudai, Y. (2011). "Following the crowd: Brain substrates of long-term memory conformity." *Science Magazine*, 333, 108-111.

**6) Which of the following could be used to explain the change from Test 2 to Test 3 in the no-manipulation group as depicted in Figure 1?**

- A. Memory cues
- B. Memory decay
- C. Memory interference
- D. Memory consolidation

Answer: B

Foundational Concept: 6

Content Category: 6B

Skill: 4

**7) Which type of memory was used to examine memory conformity in the described study?**

- A. Sensory memory
- B. Episodic memory
- C. Semantic memory
- D. Procedural memory

Answer: B

Foundational Concept: 6

Content Category: 6B

Skill: 1

**8) How does cognitive dissonance explain the occurrence of persistent conformity? Memories change to reduce discomfort resulting from providing answers that differ from:**

- A. answers identified as correct.
- B. memories of others.
- C. previously provided answers.
- D. original memories.

Answer: D

Foundational Concept: 7

Content Category: 7A

Skill: 1

**9) Which conclusion is NOT supported by the data in Figure 2?**

- A. Enhanced activity in the amygdala was related specifically to socially-induced persistent memory errors.
- B. Increased activity of the hippocampus was associated with persistent memory errors regardless of manipulation type.
- C. Hippocampus activation differentiates between persistent and transient errors regardless of the source of influence.
- D. Transient memory errors activated areas crucial for memory processing only when information was presented in a social context.

Answer: D

Foundational Concept: 6

Content Category: 6B

Skill: 4

**10) Which of the following theories would be supported if participants changed their memories to align with only co-observers of the same religious denomination?**

- A. Social learning theory
- B. Social identity theory
- C. Modern prejudice theory
- D. Levels-of-processing theory

Answer: B

Foundational Concept: 8

Content Category: 8B

Skill: 1

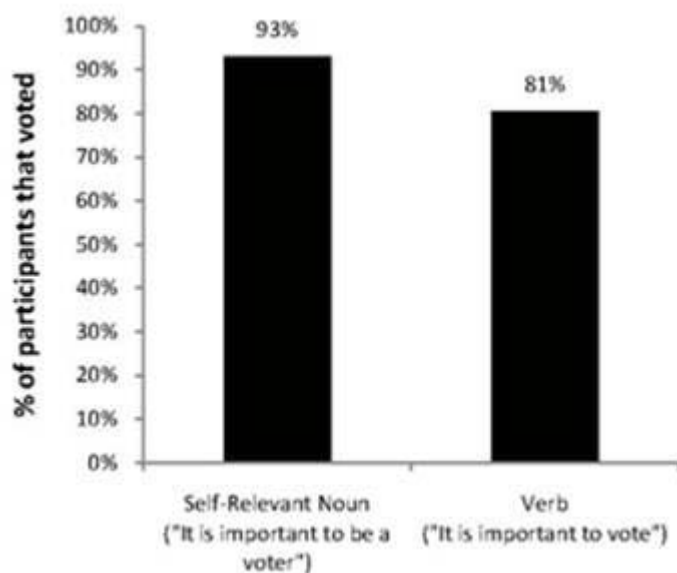


### Sample Passage 3: Questions 11-15

Social scientists have found that people have a strong desire to cultivate and maintain a positive self-image. More often than not, people want to see themselves as generally good, competent, and worthy of social approval. They also want others to perceive them this way as well.

A recent study examined behavior related to these concepts of self-image. In most Western societies, the act of voting is regarded as a socially-responsible behavior and voters are typically described as good people and upstanding citizens. Researchers mailed one of two versions of a survey to registered voters just before national and local elections. The different versions of the survey involved the manipulation of word choice to frame voting as either a personal identity using a self-relevant noun (i.e., “voter”) or a behavior using a verb (i.e., “vote”). Thus, participants received a survey that asked them to either indicate whether they thought voting is important (i.e., verb) or whether being a voter is important (i.e., self-relevant noun). Official voting records for participants revealed that, on average, overall voter turnout was higher among those who received the survey that used a self-relevant noun (i.e., “voter”) than the participants who received the survey that used a verb (i.e., “vote”).

The figure below illustrates the results of this study.



**Figure 1.** Percentage of Participants that Voted by Word Choice Manipulation.

Source: Adapted from Bryan, C. J., Walton, G. M., Roger, T., & Dweck, C. S. (2011). “Motivating voter turnout by invoking the self.” *Proceedings of the National Academy of the Sciences of the United States of American*, 108(31).

**11) The use of the self-relevant noun most likely acted on the participants' self-concept in all of the following ways EXCEPT which one?**

- A. Participants thought about their past behaviors.
- B. Participants evaluated their immediate feelings.
- C. Participants imagined their ideal selves.
- D. Participants conducted a brief self-assessment.

Answer: B

Foundational Concept: 8

Content Category: 8B

Skill: 2

**12) Which of the following explanations describes why the Identity vs. Role Confusion stage likely affects views about voting and being a voter? During that stage people are:**

- A. establishing a philosophy of life.
- B. perpetuating and transmitting culture.
- C. gaining life experiences to provide bedrock for their ideals.
- D. contributing to the betterment of society.

Answer: A

Foundational Concept: 8

Content Category: 8A

Skill: 1

**13) If this study were replicated in a collectivist society, which of the following manipulations would most likely increase the likelihood that participants would vote? Using:**

- A. a self-relevant noun
- B. an other-relevant noun
- C. a self-relevant verb
- D. an other-relevant verb

Answer: B

Foundational Concept: 7

Content Category: 7B

Skill: 2

**14) How might dramaturgy theory explain this study's findings? The use of the:**

- A. Self-relevant noun acted on participants' front-stage selves.
- B. Self-relevant verb acted on participants' back-stage selves.
- C. Self-relevant noun acted on participants' back-stage selves.
- D. Self-relevant verb acted on participants' front-stage selves.

Answer: A

Foundational Concept: 8

Content Category: 8C

Skill: 2

**15) What result would you predict if the researchers manipulated "recycling" instead of "voting?"**

- A. An increased likelihood of recycling for the self-relevant noun.
- B. An increased likelihood of recycling for the verb.
- C. A decreased likelihood of recycling for the self-relevant noun.
- D. A decreased likelihood of recycling for the verb.

Answer: A

Foundational Concept: 8

Content Category: 8A

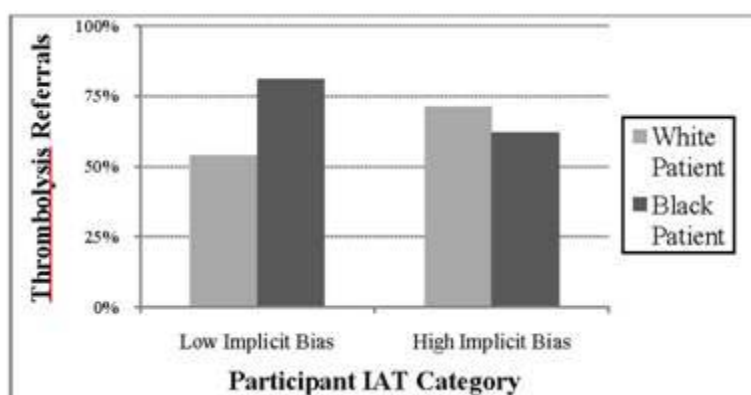
Skill: 3

## Sample Passage 4: Questions 16-20

Psychologists have identified two distinct forms of bias: explicit and implicit bias. An explicit bias is a conscious preference, whereas an implicit bias is an unconscious preference. Research investigating racial disparities in treatments for heart attacks has found that Blacks are significantly less likely than Whites to receive thrombolytic therapy (i.e., the administration of drugs to break up or dissolve blood clots).

A recent study investigated the relationship between physicians' implicit and explicit biases and their decisions to provide thrombolytic therapy to Black and White patients. Residents were recruited to participate in an online study. Participants received a vignette describing a 50-year-old male who displayed heart attack symptoms. Half the sample's vignettes included a photo of a Black patient, while the other half were provided with a photo of a White patient.

After indicating whether or not they would refer the patient for thrombolysis therapy, participants' explicit preferences for Blacks and Whites were measured using a 5-point Likert scale. Next, participants completed an implicit association task (IAT). The IAT assessed participants' implicit bias by measuring their response time to valenced words (e.g., words with good or bad connotations) presented with images of Black and White individuals. No effect was found for levels of explicit bias and the likelihood of providing thrombolysis therapy. Figure 1 summarizes the study's findings related to implicit bias.



**Figure 1.** Percent of Participants Referring Patients for Thrombolytic Therapy as a Function of Participants' Levels of Implicit Bias and Patient Race.

Source: Adapted from Green, R. A., et al. (2007). "Implicit bias among physicians and its prediction of thrombolysis decisions for Black and White patients." *Journal of General Internal Medicine*, 22, 1231-1238.

**16) Which concept is the focus of this study?**

- A. Fundamental attribution error
- B. Elaboration likelihood model
- C. Modern prejudice
- D. Self-serving bias

Answer: C

Foundational Concept: 8

Content Category: 8B

Skill: 1

**17) Which of the following explanations describes why the amygdala would most likely be activated by the use of the IAT in this study? The amygdala is important for:**

- A. learning.
- B. fear.
- C. anxiety.
- D. value judgments.

Answer: B

Foundational Concept: 7

Content Category: 7A

Skill: 1

**18) How would a Social Identity Theorist most likely explain the results summarized in Figure 1?**

- A. The physician is ethnocentric and places high value on belonging to his racial in-group.
- B. The physician perceives Blacks as competing against Whites for scarce societal resources.
- C. The physician is a product of prejudiced parents and peers.
- D. The physician is surrounded by inaccurate stereotypes.

Answer: A

Foundational Concept: 8

Content Category: 8A

Skill: 1

**19) Self-monitoring refers to adjusting one's self-presentation to ensure appropriate or desired public appearances. If this study was extended to investigate self-monitoring, which of the following results would you expect from high self-monitoring physicians? Prescribe treatment:**

- A. at the same rate for Blacks and Whites when they are high in implicit bias.
- B. at a lower rate for Black than Whites when they are high in implicit bias.
- C. for Blacks and Whites at a higher rate, regardless of their level of implicit bias
- D. for Whites at a lower rate, regardless of their level of implicit bias

Answer: A

Foundational Concept: 7

Content Category: 7A

Skill: 2

**20) Which of the following conclusions is supported by the findings?**

- A. Participants high in implicit bias prescribed thrombolytic therapy for Black patients more often than for White patients.
- B. Participants prescribed thrombolytic therapy less than 50% of the time for all patients, regardless of their implicit bias levels.
- C. Participants high in implicit bias prescribed thrombolytic therapy for Black patients 77% of the time.
- D. Participants high in implicit bias prescribed thrombolytic therapy for White patients more often than for Black patients.

Answer: D

Foundational Concept: 8

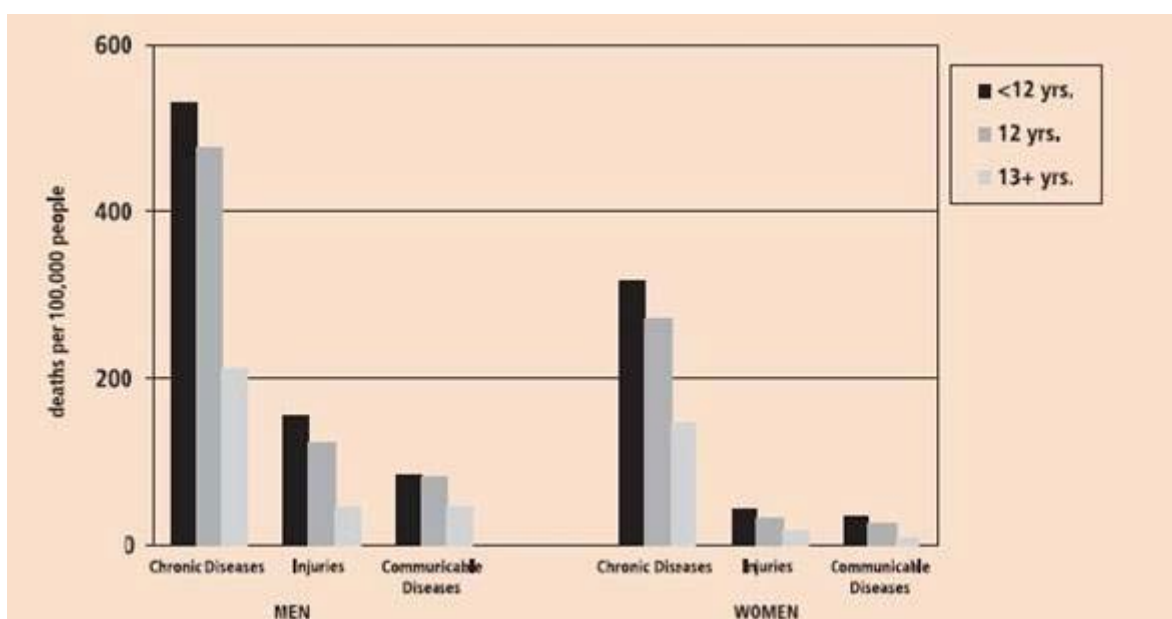
Content Category: 8B

Skill: 4

## Sample Passage 5: Questions 21-23

Despite the United States spending more on health care than any other developed nation, Americans comprise one of the least healthy populations when compared to the populations of other developed nations. Many social scientists agree that this trend is due to health care disparities between rich and poor Americans.

Social conditions play a major role in determining a person's overall health. Race and ethnicity, gender, and socioeconomic status can affect health outcomes, as can specific social institutions like the workplace or schools. A study conducted by the Centers for Disease Control and Prevention found that as education levels increased, death rates decreased (see Figure 1). Health risks are more likely to be understood by individuals with more education, which allows them to mitigate these risks more than their less educated counterparts.



**Figure 1.** Death Rates across Different Modes of Mortality as a Function of Years of Education and Gender

**21) How would conflict theory explain the findings of the study?**

- A. Women are more highly educated than men and therefore have better health outcomes.
- B. Wealthy have better health outcomes than the poor because they have access to better health care.
- C. Schools provide students with the tools necessary to make appropriate health decisions.
- D. Education provides students with values attached to the concepts of health and illness.

Answer: B

Foundational Concept: 10

Content Category: 10A

Skill: 2

**22) Which of the following conclusions is supported by the findings?**

- A. College education is associated with better health outcomes.
- B. It is more important to educate women about communicable disease prevention than men.
- C. Women are more likely than men to die from chronic disease regardless of their education level.
- D. Lower levels of education leads to poorer health outcomes for men but not for women.

Answer: A

Foundational Concept: 10

Content Category: 10A

Skill: 4

**23) Which of the following conclusions is supported by the data presented in Figure 1? Level of education is:**

- A. positively associated with death rates and the effect is stronger for men.
- B. positively associated with death rates, regardless of cause of death.
- C. negatively associated with death rates, but the effect is stronger for women.
- D. negatively associated with death rates, regardless of gender.

Answer: D

Foundational Concept: 10

Content Category: 10A

Skill: 4



**Sample Items: Questions 24-28** (these questions are not associated with passages)

**24) Brain imaging was conducted on participants to gather baseline data and then again while participants watched a video demonstrating how to sew a button on a shirt (i.e., Time 2). Which of the following would you predict when comparing participants' brain images at baseline to Time 2?**

- A. Increased blood flow in the hippocampus
- B. Increased blood flow in the hypothalamus
- C. Increased mirror neuron activity
- D. Increased serotonin activity

Answer: C

Foundational Concept: 7

Content Category: 7C

Skill: 2

**25) Participants watched two people play a board game and then completed an observation sheet indicating how often the players helped each other or taunted each other. Which of the following additions would allow researchers to investigate locus of control? Ask participants if they:**

- A. feel capable of observing others without bias.
- B. feel luck plays a major role in people's lives.
- C. believe cheating will help players win the game.
- D. feel responsible for the happiness of other people.

Answer: B

Foundational Concept: 8

Content Category: 8A

Skill: 3

**26) Which area of the brain is activated relative to a flashbulb memory?**

- A. Amygdala
- B. Cerebral cortex
- C. Hypothalamus
- D. Medulla

Answer: A

Foundational Concept: 6

Content Category: 6B

Skill: 1

**27) Researchers asked participants to rate the importance of several tasks for performing a job. Thirty minutes later they asked participants to rate the tasks again, but this time the tasks were paired with a random rating. Participants were told that ratings were averages provided by their peers. Then, they asked participants to rate the tasks again. Which of the following results would you predict when comparing results from the first and second rating? Participants rated tasks with:**

- A. lower “peer ratings” as more important the second time.
- B. moderate “peer ratings” as less important the second time.
- C. higher “peer ratings” as more important the second time.
- D. the same, regardless of “peer ratings.”

Answer: C

Foundational Concept: 7

Content Category: 7B

Skill: 2

**28) Which of the following is most likely to be affected by a person’s self-concept?**

- A. Ability to memorize facts
- B. Reactions to stressful situations
- C. Problem solving
- D. Social loafing

Answer: B

Foundational Concept: 8

Content Category: 8A

Skill: 1

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

The *Critical Analysis and Reasoning Skills* section of MCAT<sup>2015</sup> is designed to test the analysis and reasoning skills you will need in medical school. It tests your skill at comprehending new information presented in a passage; evaluating and analyzing the interrelationships of passage assumptions, evidence, examples, arguments and counter-arguments; applying passage information to situations outside the immediate scope or context of the reading passage; and incorporating or integrating additional information into the passage.

The passages on the test address topics from a wide range of disciplines in the social sciences and humanities. Among them are passages about ethics, philosophy, cross-cultural studies, and population health. Everything you need to know to answer test items can be found in the reading passages and the items themselves. No additional coursework or specific knowledge of these disciplines is required to do well on this section.

The following paragraphs provide detailed information about the ways in which analysis and reasoning skills are evaluated, and the topics on which passages are based.

### Analysis and Reasoning Skills

Below are descriptions of the four broad analysis and reasoning skills on which you will be tested. It might be helpful to think of these four analysis and reasoning skills as making up a continuum. At the beginning are comprehension questions, calling on your ability to recognize and paraphrase or summarize the meaning. More complex analysis is required at the next level, where evaluation questions require dissection and critique of the "big picture." Finally, both application and incorporation questions test your synthesis, adaption, and reinterpretation of concepts previously processed and analyzed.

#### Comprehension

Items testing comprehension skills require you to understand the meaning of new information, or to think about concepts or facts you already know in a new way. Passages present concepts in a way that is accessible to readers with no prior knowledge of the topic. This is done through the use of explanations, illustrative examples, and definitions of significant specialized terms.

Comprehension items may ask you for 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 of the passage, examples, or something slightly more complex, such as portions of the passage where the author digresses from the central theme.

You may encounter comprehension items that ask you to explain paradoxes or a highlighted word or phrase — the meaning of which is not readily available, but rather is acquired from the context of the passage. You may be asked to identify points of view, other than the author's, presented indirectly through authorial summaries or paraphrases.

It is important to be aware of *how* things are said, as well as *what* is said. The author's tone (e.g., humorous, authoritative) is crucial in determining the meaning of the text. Comprehension items may ask you about something not specifically stated in the passage. This will require you to make assumptions based on what the author merely hints at through his or her use of connotative language or figures of speech.

Note how the passage concludes. Does it have a definitive solution, a partial resolution, or a call for additional research? Does it end with dramatic rhetoric, or a joke that leaves unanswered questions? You should be able to identify what is explicitly stated, as well as any clarifying information that might be missing.

Pay attention to the structure of the passage, and the author's approach. When a piece is well-written, the sequence and way the material is organized, presented, and developed aid in understanding its content. Identify how ideas are organized in the passage: Does the author develop points chronologically, present conflicting opinions on a topic in a point/counter-point fashion, or speculate on future implications of a contemporary event?

All these factors will help you to discover nuances of meaning in passage content. Above all, remember, you will not be able to answer comprehension questions correctly on the basis of your common sense or general knowledge *without a careful reading of the passage*.

## Evaluation

Evaluation items assess your skill at analyzing and determining the significance of and relationships among different parts of a passage. They differ from comprehension items by directing your attention to an argument, claim, or theme in the passage; then asking you to judge its logic and plausibility, the soundness of its arguments, the reasonableness of its conclusions, the aptness of its generalizations, or the credibility of the author and his or her sources of information. Evaluation items test your skill at going beyond the content's surface to examine evidence, biases, faulty notions of causality, and irrelevant information.

While evaluation items draw more heavily on logic and reason, you may be required to analyze the author's language, tone, and purpose in the process of evaluating a passage. For example, plausible-sounding, transitional phrases may, on the surface, 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.

When it comes to judging the intentions and credibility of an author as the passage's sole source of information, look for clues in the form of vague, evasive terms, or self-aggrandizing language — not just contradictions, omissions of key facts, or a lack of relevant examples. Traditionally, a credible source is both authoritative and capable of objectivity. It is someone who has specific expertise in the area about which he or she is speaking, as may be indicated in the passage by a person's title, level of education, or previous publications. That having been said, even the most credentialed author fails in his or her argument if it is constructed from propaganda, has the appearance of being motivated by a monetary incentive to "sell" an idea, or exhibits irrefutable bias toward opponents or members of a particular demographic.

Blatant, one-sided arguments and rigid points-of-view are easy to identify. The key to identifying bias lies in identifying the author's *treatment* of ideas, which is achieved 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.

When approaching evaluation questions, it is important to remember that you are not being asked to provide your own personal opinion. You may, in fact, disagree with the author's overall conclusion, yet find that 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. You are scored based on your answers to the content of the passage provided. *The content of the passage* is the *only* information on which your responses should be based.

## Application

Underlying virtually all application items is a concern with how the information or ideas presented in the passage could be extended to other areas or fields, thereby advancing knowledge. Application items assess high-level analysis and reasoning skills by asking examinees to combine selected ideas, which may or may not result in a successful combination or outcome.

Clearly, not every combination of elements is successful — or even feasible. Ideas, like plants, may be successfully transplanted to one location, while failing in another. For each application item, your task is to gauge, through a choice of response options, the likely outcome of applying passage content as is to a new context outside the terrain of the passage. The passage material is the given; the directions for transplanting its ideas come from the test item, not in the passage. You will then be required to combine the elements from the passage with the 'transplanting' context provided in the item and, using your analysis and reasoning skills, determine the likely outcome.

Each response option will yield a different result, but each test item has only one defensible and demonstrably correct response option. The correct answer is the one that describes the most likely and most reasonable outcome, based on the information provided. For example, if an item asked you to determine the author's likely response to a hypothetical situation, you would choose the response option most consistent with what the author has already said or done according to the text of the passage.

Ideas can only be combined seamlessly where points of congruence exist. Therefore, ruling out response options that couldn't fit the framework of the passage material is necessary. For example, the topic of a passage is that election reform increased voter turnout in country A. The item provides you with the context for country B and asks you to choose the likely outcome if country B were to undergo election reform. For this item, you should ask yourself whether there are similarities between the two countries that might make the reform in country A applicable to country B. Are the relevant aspects of their political system in the two counties similar, or are they significantly different? If the latter is the case, there are no defensible grounds for choosing country B as a promising venue for extending country A's reforms.

## Incorporation of Information

Incorporation and application items share some of the same cognitive elements. Both types deal with combinations, comparisons, and dynamic change, and both test flexibility. The essential difference between the two is that incorporation items take, as their fixed starting point, a specific piece of new information, and they assess how ideas in the passage might be affected by its introduction. Instead of applying ideas to new contexts (like application items), incorporation items require you to reinterpret and reassess passage content with the additional fact or idea introduced in the item.

In incorporation items, you may be asked to analyze what relationship the additional element has to the existing information in the passage. Does it support or contradict the passage? Could it 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 item might ask what modifications or alterations might need to be made *in the passage* to accommodate the new element introduced in the item.

Other incorporation items may ask you to select which fact or assertion would, when added to passage content, result in the least amount of change. In this case, you would look for the response option that is most similar to the situation or argument outlined in the passage. In other words, you will consider which new fact or assertion could be added to the passage with the least amount of alteration to the passage content.

Some other incorporation items are based on analogies that assess your skill at identifying a common feature shared by seemingly different concepts or assumptions. For this type of incorporation items, you might first determine whether one 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. If only one of the response options can be easily integrated into the conceptual framework of the passage, then you have the correct answer. The skill required here is much like that required to integrate new scientific findings with the existing body of knowledge that comprises medical science.

## 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 the following disciplines:

- Architecture,
- Art,
- Dance,
- Ethics,
- Literature,
- Music,
- Philosophy,
- Popular Culture,
- Religion, and
- 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 drawn from the following disciplines:

- Anthropology,
- Archaeology,
- Cross-cultural Studies,
- Economics,
- Education,
- Geography,
- History,
- Linguistics,
- Political Science,
- Population Health,
- Psychology, and
- 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.

## Sample Test Items<sup>9</sup>: *Critical Analysis and Reasoning Skills*

Sample test questions for the *Critical Analysis and Reasoning Skills* section are provided below. The answer keys appear below the questions, along with the skills the questions are testing. These sample questions will give you an idea of what to expect from this section of the exam.

### Sample Passage 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.

<sup>9</sup> These sample passages and items have not followed the same review and field-test procedures as do operational test materials.



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 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: Evaluation

**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: Application

**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: Incorporation of Information

**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: Incorporation of Information

**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: Comprehension

## Sample Passage 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 “Indianness” 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: Evaluation

**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: Application

**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: 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: Incorporation of Information

**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: Evaluation

**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: Comprehension

## Sample Passage 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: Application

**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: Application

**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: Evaluation

**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: 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: 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: Incorporation of Information

## Sample Passage 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: 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: 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: Application

**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: Incorporation of Information

**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: Evaluation

## Chapter 8: What Preparation Products and Services are Available?

### Products and Services to Help Prospective Examinees Prepare

The AAMC offers low-cost test preparation materials and services to all students, and will continue this practice for MCAT<sup>2015</sup>. In addition to the *Preview Guide*, the MCAT website includes a section dedicated to the new exam — including information about test preparation. Short, informational videos will also be available on the MCAT<sup>2015</sup> website. The first will be posted in December 2011. It will feature a medical student and a resident talking about what the new exam will be like; how you might prepare; and a little about their personal experiences related to the MCAT® exam.

In 2014, the AAMC will release a full-length practice test. The practice test will mirror the actual exam. This will provide you the opportunity to practice with both the interface and functionality of the exam and get some practice with test items just like those that will be on the actual exam. The MCAT<sup>2015</sup> practice test will offer you several options for taking the test. One useful option is “Simulate the Actual Test”, which delivers the exam under timed conditions, including timed breaks. This option gives you the opportunity to experience what the test will be like prior to test day. After completing the practice test, you will get a report summarizing your results. You will also be able to return to the practice test to review the answers and solutions for every item, making this a great learning tool.

Also in 2014, *The Official Guide to MCAT<sup>2015</sup>* will be released. Similar to the current guidebook, *The Official Guide to the MCAT® Exam*, the new guidebook will provide an overview of all the information you will need to help ensure a positive MCAT experience. *The Official Guide to MCAT<sup>2015</sup>* will be organized into two sections. The first section of the new guidebook will provide an overview of “everything MCAT,” including 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 for which you are responsible. It will also include a set of practice items 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. You will again have the option to simulate actual test conditions, or you may choose another delivery option that allows for more targeted practice. And, as with all practice tests, you will have the opportunity to review the answers and solutions for every test item once the practice test is completed.

Be sure to visit our website to stay up-to-date with all the latest MCAT<sup>2015</sup> test preparation products and services the AAMC offers: [www.aamc.or/mcat2015](http://www.aamc.or/mcat2015).

## Products and Services to Support Pre-health Advisors and Other Baccalaureate Faculty

The AAMC appreciates the critical role pre-health advisors and other baccalaureate faculty play in preparing students for a career in medicine, and want to help them become familiar with the content of the future exam. In support of this goal and to help ensure everyone has access to the information they need, the AAMC will offer informational presentations at national meetings and host a series of webinars. Information, along with the requisite online registration forms, will soon be available on our website: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

We at the AAMC are committed to working with pre-health advisors, other undergraduate faculty, and medical school admissions officers to help ensure all students have opportunities to succeed on the MCAT exam. Recognizing that the introduction of a new exam raises concerns within the community — how to ensure students master the necessary knowledge and skills prior to sitting for the exam, which undergraduate courses provide students with the opportunity to develop these, and which methods of instruction best target exam concepts — AAMC currently has two projects in development to provide additional support.

- The AAMC understands that course content differs between schools and that some colleges organize courses following traditional disciplinary structures, while others offer innovative, interdisciplinary courses. This can create some confusion for students as they try to identify courses at their institutions that will help them develop the knowledge and skills they need for the MCAT<sup>2015</sup> exam. Working to address this concern, the AAMC is developing tools to help faculty, advisors, and students map the content lists onto the courses at their institutions that teach the knowledge and skills targeted by the exam.
- In order to help undergraduate faculty find instructional resources that will be helpful in preparing for MCAT<sup>2015</sup>, the AAMC is developing a curriculum-sharing project. The idea is to create an online resource where faculty can:
  - access examples of instructional resources that teach the concepts the exam will test and that provide a solid foundation for the first year of medical school;
  - get ideas on how to best teach specific concepts; or
  - find modules to use directly in class instruction.

More details about these projects will be posted on our website as they develop:  
[www.aamc.org/mcat2015](http://www.aamc.org/mcat2015).

Additionally, the AAMC will be producing a variety outreach materials (e.g., brochures and bookmarks), and a series of short, and as already mentioned, informational videos to help pre-health advisors and other faculty discuss MCAT<sup>2015</sup> with their students.

## Chapter 9: Where can Additional Information about MCAT<sup>2015</sup> be Found?

You can find more information about MCAT<sup>2015</sup> and the information and activities that shaped its design at the following websites.

Information about MCAT<sup>2015</sup> for prospective examinees: [www.aamc.org/mcat2015](http://www.aamc.org/mcat2015)

Information about MCAT<sup>2015</sup> for pre-health advisors and other baccalaureate faculty: [www.aamc.org/mcat2015/admins](http://www.aamc.org/mcat2015/admins)

Information about MCAT<sup>2015</sup> 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:

MR5 Update, Fall 2011: [www.aamc.org/mr5/fall2011.pdf](http://www.aamc.org/mr5/fall2011.pdf)

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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