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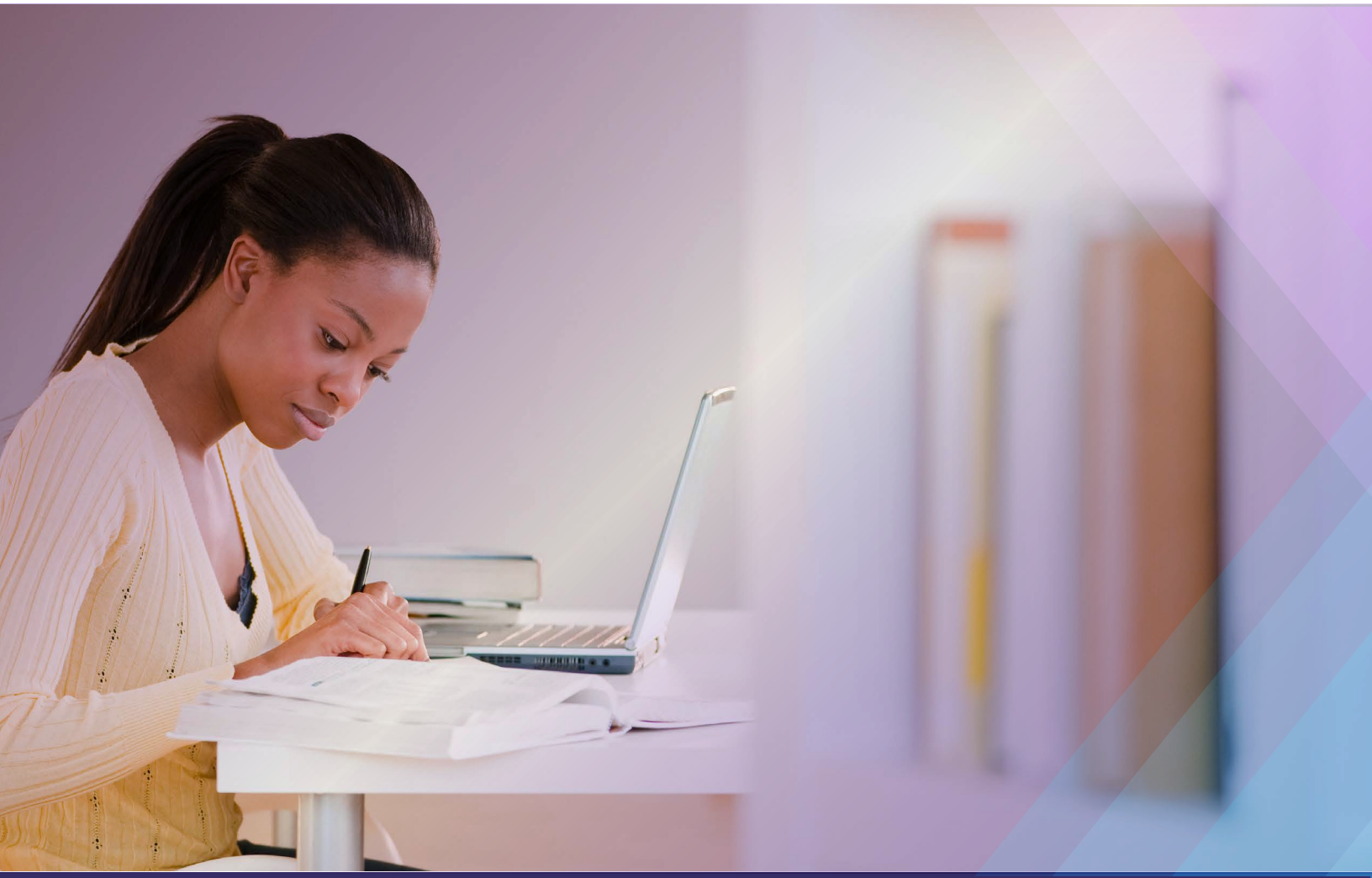
Medical College Admission Test®

What's on the MCAT® Exam?



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Contents

Introduction 2

Scientific Inquiry and Reasoning Skills 4

Biological and Biochemical Foundations of Living Systems 17

Chemical and Physical Foundations of Biological Systems 50

Psychological, Social, and Biological Foundations of Behavior 75

Critical Analysis and Reasoning Skills 101

Introduction

This document draws from the online resource *What's on the MCAT® Exam?* at students-residents.aamc.org/mcatexam. It contains a complete description of the competencies you are responsible for knowing on the MCAT exam. It describes the exam's content and format. It also lists and discusses the exam's conceptual framework, organized around foundational concepts, content categories, and scientific inquiry and reasoning skills. Also included are sample test questions that demonstrate how the competencies are tested on the exam. While the content is written for you, the prospective MCAT examinee, the information it provides is likely to be useful to prehealth advisors, other baccalaureate faculty, medical school admissions officers, and medical schools.

How Is the MCAT Exam Structured?

The MCAT exam has four test sections:

- Biological and Biochemical Foundations of Living Systems
- Chemical and Physical Foundations of Biological Systems
- Psychological, Social, and Biological Foundations of Behavior
- Critical Analysis and Reasoning Skills

The first three sections 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 knowledge simply of many discrete scientific facts.

Leaders in science education say some of the most important foundational concepts in the sciences ask students to integrate and analyze information from different disciplines. In that vein, questions in these sections will ask you to combine your scientific knowledge from multiple disciplines with your scientific inquiry and reasoning skills. You will be asked to demonstrate four different scientific inquiry and reasoning skills on the exam:

- Knowledge of scientific concepts and principles.
- Scientific reasoning and problem-solving.
- Reasoning about the design and execution of research.
- Data-based and statistical reasoning.

The fourth section of the MCAT exam, Critical Analysis and Reasoning Skills, will be similar to many of the verbal reasoning tests you have taken in your academic career. It includes passages and questions that test your ability to comprehend and analyze what you read. The Critical Analysis and Reasoning Skills section asks you to read and think about passages from a wide range of disciplines in the social sciences and humanities, including those in population health, ethics and philosophy, and studies of diverse cultures. Passages are followed by a series of questions that lead you through the process of

comprehending, analyzing, and reasoning about the material you have read. This section is unique because it has been developed specifically to measure the analytical and reasoning skills you will need to be successful in medical school.

Scientific Inquiry and Reasoning Skills

Leaders in medical education believe tomorrow's physicians need to be able to combine scientific knowledge with skills in scientific inquiry and reasoning. With that in mind, the MCAT exam will ask you to demonstrate four scientific inquiry and reasoning skills that natural, behavioral, and social scientists rely on to advance their work:

Knowledge of Scientific Concepts and Principles
• Demonstrating understanding of scientific concepts and principles. • Identifying the relationships between closely related concepts.

Scientific Reasoning and Problem-Solving
• Reasoning about scientific principles, theories, and models. • Analyzing and evaluating scientific explanations and predictions.

Reasoning About the Design and Execution of Research
• Demonstrating understanding of important components of scientific research. • Reasoning about ethical issues in research.

Data-Based and Statistical Reasoning
• Interpreting patterns in data presented in tables, figures, and graphs. • Reasoning about data and drawing conclusions from them.

The discussion that follows describes each of the skills and how you may be asked to demonstrate them. Three sample test questions are provided to illustrate each skill: one from the Psychological, Social, and Biological Foundations of Behavior section; one from the Biological and Biochemical Foundations of Living Systems section; and one from the Chemical and Physical Foundations of Biological Systems section. Also included are explanations of how each question tests a specific scientific inquiry and reasoning skill.

Skill 1: Knowledge of Scientific Concepts and Principles

The questions in this skill category will ask you to demonstrate your knowledge of the 10 foundational concepts described in subsequent chapters. These questions will ask you to recognize, identify, recall, or define basic concepts in the natural, behavioral, and social sciences as well as their relationships with one another. The concepts and scientific principles may be represented by words, graphs, tables, diagrams, or formulas.

As you work on these questions, you may be asked to identify a scientific fact or define a concept. Or you may be asked to apply a scientific principle to a problem. Questions may ask you to identify the relationships between closely related concepts or relate written statements, principles, or concepts to graphic representations of science content. They may ask you to identify examples of natural or data-driven observations that illustrate scientific principles. Questions may ask you to recognize a scientific concept shown in a diagram or represented in a graph.

Or they may give you a mathematical equation and ask you to use it to solve a problem.

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

- Recognizing scientific principles from an example, situation, or study. Identifying the relationships among closely related concepts.
- Identifying the relationships between different representations of concepts (e.g., written, symbolic, graphic).
- Identifying examples of observations that illustrate scientific principles.
- Using given mathematical equations to solve problems.
- Identifying the simple or familiar molecule that is an example of a specific amino acid.

By way of example, questions from the Psychological, Social, and Biological Foundations of Behavior section may ask you to demonstrate your knowledge of scientific concepts and principles by:

- Recognizing the principle of retroactive interference.
- Using Weber's law to identify physical differences that are detectable.
- Identifying the behavioral change (extinction) that will occur when a learned response is no longer followed by a reinforcer.
- Identifying the conceptual similarities or differences between operant conditioning and classical conditioning.
- Identifying a graph that illustrates the relationship between educational attainment and life expectancy.
- Recognizing conditions that result in learned helplessness.
- Concluding which stage of cognitive development a child is in, according to Piaget's theory, when presented with a description of how a child responds to a conservation problem.

The three sample questions that follow illustrate Skill 1 questions from, respectively, the Psychological, Social, and Biological Foundations of Behavior section; the Biological and Biochemical Foundations of Living Systems section; and the Chemical and Physical Foundations of Biological System section of the MCAT exam.

Skill 1 Example From the Psychological, Social, and Biological Foundations of Behavior Section

In a study, each trial involves administering a drop of lemon juice to the participant's tongue and measuring the participant's level of salivation. As more trials are conducted, the researcher finds that the magnitude of salivation declines. After a certain point, the researcher switches to administering lime juice. This researcher is most likely studying which process?

A. Sensory perception
B. Habituation and dishabituation
C. Stimulus generalization in classical conditioning
D. Conditioned responses in classical conditioning

The correct answer is B. This Skill 1 question tests your knowledge of the scientific concepts and principles described by Content Category 7C, *Attitude and behavior change* (see page 90), and is a Skill 1 question because it requires you to relate scientific concepts. This question asks you to identify the process involved in the study that connects reduced responding to a repeated stimulus and then a change in the stimulus, which is habituation and dishabituation, allowing for the conclusion that B is the correct answer.

Skill 1 Example From the Chemical and Physical Foundations of Biological Systems Section

What type of functional group is formed when aspartic acid reacts with another amino acid to form a peptide bond?

A. An amine group
B. An aldehyde group
C. An amide group
D. A carboxyl group

The correct answer is C. This is a Skill 1 question and relates to Content Category 5D, *Structure, function, and reactivity of biologically relevant molecules.* It is a Skill 1 question because you must recognize the structural relationship between free amino acids and peptides. To answer the question, you must know that the functional group that forms during peptide bond formation is an amide group.

Skill 2: Scientific Reasoning and Problem-Solving

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

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

For example, you will be asked to show you can use scientific principles to solve problems by:

- Reasoning about scientific principles, theories, and models to make predictions or determine consequences.
- Analyzing and evaluating the validity or credibility of scientific explanations and predictions.
- Evaluating arguments about causes and consequences to determine the most valid argument when using scientific knowledge.
- Bringing together theory, observations, and evidence to draw conclusions.
- Recognizing or identifying scientific findings from a given study that challenge or invalidate a scientific theory or model.
- Determining and using scientific formulas to solve problems.
- Identifying the bond that would form between two structures if they were adjacent to each other.

By way of illustration, questions from the Psychological, Social, and Biological Foundations of Behavior section may ask you demonstrate this skill by:

- Using the main premises of symbolic interactionism, use reasoning in an observational study of physician-patient interactions to describe how the premises are connected to perceived patient compliance.
- Predicting how an individual will react to cognitive dissonance.
- Using reasoning to determine whether a causal explanation is possible when given an example of how someone's gender or personality predicts his or her behavior.
- Explaining how an example, such as when an anorexic teenager restricts eating to satisfy esteem needs, is compatible with the premises of Maslow's hierarchy of needs.
- Drawing a conclusion about which sociological theory would be most consistent with a conceptual diagram that explains how social and environmental factors influence health and why this theory is most consistent.
- Identifying the relationship between social institutions that is suggested by an illustration used in a public health campaign.
- Recognizing a demographic trend that is represented in a population pyramid.

For more context, let's consider three Skill 2 questions linked to different foundational concepts in the Psychological, Social, and Biological Foundations of Behavior section; the Biological and Biochemical Foundations of Living Systems section; and the Chemical and Physical Foundations of Biological Systems section.

Skill 2 Example From the Psychological, Social, and Biological Foundations of Behavior Section

Which statement describes what the concept of cultural capital predicts?

A. Cultural distinctions associated with the young will be more valued within a society.
B. With improved communication, there will eventually be a convergence of cultural practices of all classes.
C. Cultural distinctions by class will become less important during a recession because people will have less money to spend.
D. Cultural distinctions associated with elite classes will be more valued within a society.

The correct answer is D. It is a Skill 2 question and assesses knowledge of Content Category 10A, *Social inequality*. It is a Skill 2 question because it requires you to make a prediction based on a particular concept. This question requires you to understand the concept of cultural capital in order to evaluate which prediction about social stratification would be most consistent with the concept.

Skill 2 Example From the Biological and Biochemical Foundations of Living Systems Section

Starting with the translation initiation codon, how many amino acids for this polypeptide does the sequence shown encode?

5'-CUGCCAAUGUGCUAAUCGCGGGGG-3'

A. 2
B. 3
C. 6
D. 8

The correct answer is A. This is a Skill 2 question, and you must use knowledge from Content Category 1B, *Transmission of genetic information from the gene to the protein*, to solve this problem. In addition to recalling the sequence for the start codon, this is a Skill 2 question because it requires you to apply the scientific principle of the genetic code to the provided RNA sequence. As a Skill 2 question, reasoning about the role of the stop codon in translation will allow you to arrive at the conclusion that this sequence codes for a polypeptide with two amino acids.

Skill 2 Example From the Chemical and Physical Foundations of Biological Systems Section

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 4×10^{-4} cm, with blood passing through at a velocity of 5×10^{-2} cm/s. Using these data, what is the approximate number of capillaries in a human body?

A. 1×10^{4}

B. 2×10^{7}

C. 4×10^{9}

D. 7×10^{12}

The correct answer is C. This Skill 2 question relates to Content Category 4B, *Importance of fluids for the circulation of blood, gas movement, and gas exchange.* This question asks you to use a mathematical model to make predictions about natural phenomena. To answer this question, you must be able to recognize the principles of flow characteristics of blood in the human body and apply the appropriate mathematical model to an unfamiliar scenario. Answering this question first requires recognition that the volume of blood flowing through the aorta is the same volume of blood flowing through the capillaries. It is a Skill 2 question because you then need to use reasoning skills to find the difference in the volumes that the aorta and capillaries can each carry in order to calculate the total number of capillaries.

Skill 3: Reasoning About the Design and Execution of Research

Questions that test reasoning about the design and execution of research will ask you to demonstrate your scientific inquiry skills by showing you can "do" science. They will ask you to demonstrate your understanding of important components of scientific methodology. These questions will ask you to demonstrate your knowledge of the ways natural, behavioral, and social scientists conduct research to test and extend scientific knowledge.

As you work on these questions, you may be asked to show how scientists use theory, past research findings, and observations to ask testable questions and pose hypotheses. Questions that test this skill may ask you to use reasoning to identify the best way for scientists to gather data from samples of members of the population they would like to draw inferences about. They may ask you to identify how scientists manipulate and control variables to test their hypotheses or to identify and determine different ways scientists take measurements and record results. The questions may ask you to identify faulty research logic or point out the limitations of the research studies that are described. Or they may ask you to identify factors that might confuse or confound the inferences you can draw from the results.

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

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

- Identifying the role of theory, past findings, and observations in scientific questioning.
- Identifying testable research questions and hypotheses.
- Distinguishing between samples and populations and between results that support and fail to support generalizations about populations.
- Identifying the relationships among the variables in a study (e.g., independent versus dependent variables; control and confounding variables).
- Using reasoning to evaluate the appropriateness, precision, and accuracy of tools used to conduct research in the natural sciences.
- Using reasoning to evaluate or determine the appropriateness, reliability, and validity of tools used to conduct research in the behavioral and social sciences.
- Using reasoning to determine which features of research studies suggest associations between variables or causal relationships between them (e.g., temporality, random assignment).
- Using reasoning to evaluate ethical issues when given information about a study.
- Determining which molecule is a product of two other molecules without rearrangement.

For example, questions from the Psychological, Social, and Biological Foundations of Behavior section may ask you to reason about the design and execution of research by:

- Identifying the basic components of survey methods, ethnographic methods, experimental methods, or other types of research designs in psychology and sociology.
- Selecting a hypothesis about semantic activation.
- Identifying the extent to which a finding can be generalized to the population when given details about how participants were recruited for an experiment in language development.
- Identifying the experimental setup in which researchers manipulate self-confidence.
- Identifying the most appropriate way to assess prejudice in a study on implicit bias.
- Using reasoning to determine or evaluate the implications of relying on self-report measures for a specific study.
- Identifying the third variable that may be confounding the findings from a correlational study.
- Making judgments about the reliability and validity of specific measures when given information about the response patterns of participants.
- Identifying whether researchers violated any ethical codes when given information about a study.

The three sample questions that follow illustrate Skill 3 questions from, respectively, the Psychological, Social, and Biological Foundations of Behavior section; the Biological and Biochemical Foundations of Living Systems section; and the Chemical and Physical Foundations of Biological Systems section of the MCAT exam.

Skill 3 Example From the Psychological, Social, and Biological Foundations of Behavior Section

Researchers conducted an experiment to test social loafing. They asked participants to prepare an annual report or a tax return. Some participants performed the task individually and others performed it as a group. What are the independent and dependent variables?

A. The independent variable is the overall productivity of the group, and the dependent variable is each participant's contribution to the task.
B. The independent variable is the type of task, and the dependent variable is whether the participants worked alone or in a group.
C. The independent variable is whether the participant worked alone or in a group, and the dependent variable is each participant's contribution to the task.
D. The independent variable is whether the participant worked alone or in a group, and the dependent variable is the type of the task.

The correct answer is C. This Skill 3 question assesses knowledge of Content Category 7B, *Social processes that influence human behavior*. This question is a Skill 3 question because it requires you to use reasoning skills in research design. This question requires you to understand social loafing and draw inferences about the dependent and independent variables based on this concept and the description of the experimental design.

Skill 3 Example from the Biological and Biochemical Foundations of Living Systems Section

Sodium dodecyl sulfate (SDS) contains a 12-carbon tail attached to a sulfate group and is used in denaturing gel electrophoresis of proteins. Numerous SDS molecules will bind to the exposed hydrophobic regions of denatured proteins. How does the use of SDS in this experiment allow for the separation of proteins?

A. by charge
B. by molecular weight
C. by shape
D. by solubility

The correct answer is B. This is a Skill 3 question and requires knowledge from Content Category 1A, *Structure and function of proteins and their constituent amino acids*. It is a Skill 3 question because it requires you to understand the design of a denaturing gel electrophoresis experiment and the role that SDS plays in this technique. Based on this understanding, you will be able to determine that proteins will be separated only by molecular weight.

Skill 3 Example From the Chemical and Physical Foundations of Biological Systems Section

A test for proteins in urine involves precipitation but is often complicated by precipitation of calcium phosphate. Which procedure prevents precipitation of the salt?

A. addition of buffer to maintain high pH

B. addition of buffer to maintain neutral pH

C. addition of calcium hydroxide

D. addition of sodium phosphate

The correct answer is B. This is a Skill 3 question and relates to Content Category 5B, *Nature of molecules and intermolecular interactions.* In this Skill 3 question, you must identify a change in an experimental approach that would eliminate a frequently encountered complication. The complication in this case is related to the test for protein-involving precipitation. The test will give a false positive if calcium phosphate precipitates. To answer this Skill 3 question, you need to use reasoning skills to determine how changing experimental parameters will eliminate the complication.

Skill 4: Data-Based and Statistical Reasoning

Like questions about Skill 3, questions that test Skill 4 will ask you to show you can "do" science, this time by demonstrating your data-based and statistical reasoning skills. Questions that test this skill will ask you to reason with data. They will ask you to read and interpret results using tables, graphs, and charts. These questions will ask you to demonstrate you can identify patterns in data and draw conclusions from evidence.

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

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

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

- Using, analyzing, and interpreting data in figures, graphs, and tables to draw a conclusion about expected results if the experiment was to be completed again.
- Evaluating whether representations are an appropriate or reliable fit for particular scientific observations and data.
- Using measures of central tendency (mean, median, and mode) and measures of dispersion (range, inter-quartile range, and standard deviation) to describe data.
- Using reasoning about random and systematic error.
- Using reasoning about statistical significance and uncertainty (e.g., interpreting statistical significance levels, interpreting a confidence interval) and relating this information to conclusions that can or cannot be made about the study.
- Using data to explain relationships between variables.
- Using data to answer research questions and draw conclusions.
- Identifying conclusions supported by research results.
- Determining the implications of results for real-world situations.
- Using structural comparisons to make predictions about chemical properties in an unfamiliar scenario.

For example, questions from the Psychological, Social, and Biological Foundations of Behavior section may ask you to demonstrate your use of data-based and statistical reasoning by:

- Identifying the correlation between a demographic variable, such as race/ethnicity, gender, or age, and life expectancy or another health outcome.
- Identifying the relationship between demographic variables and health variables reported in a table or figure.
- Explaining why income data are usually reported using the median rather than the mean.
- Using reasoning to identify or evaluate what inference is supported by a table of correlations between different socioeconomic variables and level of participation in different physical activities.
- Using reasoning about the type of comparisons made in an experimental study of cognitive dissonance and evaluating what the findings imply for attitude and behavior change.
- Drawing conclusions about the type of memory affected by an experimental manipulation when you are shown a graph of findings from a memory experiment.
- Distinguishing the kinds of claims that can be made when using longitudinal data, cross-sectional data, or experimental data in studies of social interaction.
- Identifying which conclusion about mathematical understanding in young children is supported by time data reported in a developmental study.
- Evaluating data collected from different types of research studies, such as comparing results from a qualitative study of mechanisms for coping with stress with results from a quantitative study of social support networks.

- Using data, such as interviews with cancer patients or a national survey of health behaviors, to determine a practical application based on a study's results.

The three questions that follow illustrate Skill 4 questions from, respectively, the Psychological, Social, and Biological Foundations of Behavior section; the Biological and Biochemical Foundations of Living Systems section; and the Chemical and Physical Foundations of Biological Systems section of the MCAT exam.

Skill 4 Example From the Psychological, Social, and Biological Foundations of Behavior Section

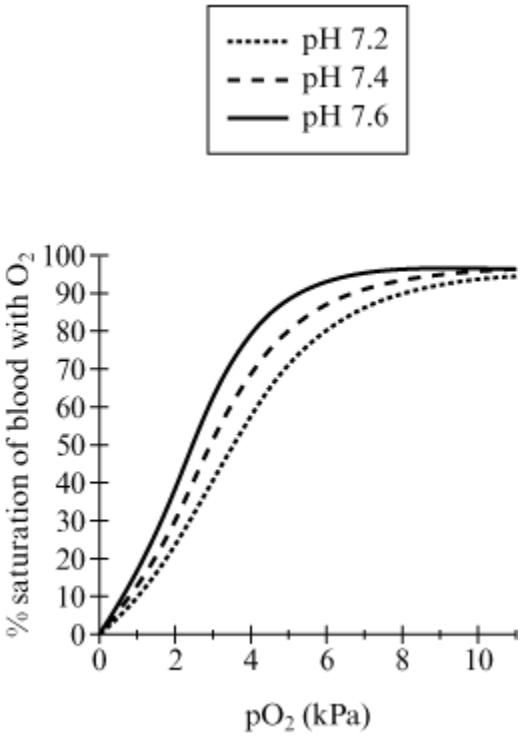
Which correlation supports the bystander effect?

A. The number of bystanders is positively correlated with the time it takes for someone to offer help in the case of an emergency.
B. The number of bystanders is negatively correlated with the time it takes for someone to offer help in the case of an emergency.
C. The number of bystanders is positively correlated with whether people judge a situation to be an emergency.
D. The number of bystanders is negatively correlated with whether people judge a situation to be an emergency.

The correct answer is A. This Skill 4 question assesses knowledge of Content Category 7B, *Social processes that influence human behavior*. It is a Skill 4 question because it requires you to engage in statistical reasoning. This question requires you to understand the distinction between negative and positive correlations and make a prediction about data based on your knowledge of the bystander effect.

Skill 4 Example From the Biological and Biochemical Foundations of Living Systems Section

In the figure, the three curves represent hemoglobin oxygen binding at three different pH values, pH 7.2, pH 7.4, and pH 7.6.



What conclusion can be drawn from these data about the oxygen binding of hemoglobin at different pH values?

A. Low pH favors the high-affinity oxygen-binding state.
B. Low pH favors the low-affinity oxygen-binding state.
C. Oxygen affinity is independent of pH.
D. Oxygen binding is noncooperative at low pH.

The correct answer is B. This Skill 4 question draws on knowledge from Content Category 1A, *Structure and function of proteins and their constituent amino acids*. This is a Skill 4 question because it asks you to use data to explain a property of hemoglobin. You must evaluate the hemoglobin oxygen-binding data for each pH value and compare them to determine the relationship between pH and hemoglobin oxygen affinity in order to conclude that low pH favors the low-affinity oxygen-binding state.

Skill 4 Example From the Chemical and Physical Foundations of Biological Systems Section

Four different solutions of a single amino acid were titrated, and the p*K* values of the solute were determined.

Solution	pK_1	pK_2	pK_3
1	2.10	3.86	9.82
2	2.10	4.07	9.47
3	2.32	9.76	Not Applicable
4	2.18	9.04	12.48

Which solution contains an amino acid that would be most likely to stabilize an anionic substrate in an enzyme pocket at physiological pH?

A. Solution 1

B. Solution 2

C. Solution 3

D. Solution 4

The correct answer is D. This Skill 4 question includes a table and assesses knowledge of Content Category 5D, *Structure, function, and reactivity of biologically relevant molecules*. Here you see that four different solutions of a single amino acid were titrated, and the p*K* values were determined. These values are found in the table. This is a Skill 4 question because you must recognize a data pattern in the table, make comparisons, and use those comparisons to make a prediction. Using knowledge of amino acids and peptide bonds and the patterns you see in the data, you can determine that the *N*- and *C*-terminus p*K* values, roughly 2 and 9 for all solutions, can be ignored since these groups will be involved in peptide bond formation. With further analyses, you can determine that only Solution 4 will be cationic at physiological pH.

Biological and Biochemical Foundations of Living Systems

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 it asks you to reason about these processes at various levels of biological organization within a living system.

This section is designed to:

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

Test Section	Number of Questions	Time
Biological and Biochemical Foundations of Living Systems	59 (note that questions are a combination of passage-based and discrete questions)	95 minutes

Scientific Inquiry and Reasoning Skills

As a reminder, the scientific inquiry and reasoning skills you will be asked to demonstrate on this section of the exam are:

Knowledge of Scientific Concepts and Principles

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

Scientific Reasoning and Problem-Solving

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

Reasoning About the Design and Execution of Research

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

Data-Based and Statistical Reasoning

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

General Mathematical Concepts and Techniques

It's important for you to know that questions on the natural, behavioral, and social sciences sections will ask you to use certain mathematical concepts and techniques. As the descriptions of the scientific inquiry and reasoning skills suggest, some questions will ask you to analyze and manipulate scientific data to show you can:

- Recognize and interpret linear, semilog, and log-log scales and calculate slopes from data found in figures, graphs, and tables.
- Demonstrate a general understanding of significant digits and the use of reasonable numerical estimates in performing measurements and calculations.
- Use metric units, including converting units within the metric system and between metric and English units (conversion factors will be provided when needed), and dimensional analysis (using units to balance equations).
- Perform arithmetic calculations involving the following: probability, proportion, ratio, percentage, and square-root estimations.
- Demonstrate a general understanding (Algebra II-level) of exponentials and logarithms (natural and base 10), scientific notation, and solving simultaneous equations.
- Demonstrate a general understanding of the following trigonometric concepts: definitions of basic (sine, cosine, tangent) and inverse ($\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$) functions; sin and cos values of 0°, 90°, and 180°; relationships between the lengths of sides of right triangles containing angles of 30°, 45°, and 60°.
- Demonstrate a general understanding of vector addition and subtraction and the right-hand rule (knowledge of dot and cross products is not required).

Note also that an understanding of calculus is *not* required, and a periodic table will be provided during the exam.

Resource

You will have access to the periodic table shown while answering questions in this section of the exam.

Periodic Table of the Elements

1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac† (227)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)

*	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

Biological and Biochemical Foundations of Living Systems Distribution of Questions by Discipline, Foundational Concept, and Scientific Inquiry and Reasoning Skill

You may wonder how much biochemistry you'll see on this section of the MCAT exam, how many questions you'll get about a particular foundational concept, or how the scientific inquiry and reasoning skills will be distributed on your exam. The questions you see are likely to be distributed in the ways described below. These are the approximate percentages of questions you'll see for each discipline, foundational concept, and scientific inquiry and reasoning skill. (These percentages have been approximated to the nearest 5% and will vary from one test to another for a variety of reasons, including, but not limited to, controlling for question difficulty, using groups of questions that depend on a single passage, and using unscored field-test questions on each test form.)

Discipline:

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

Foundational Concept:

- Foundational Concept 1, 55%
- Foundational Concept 2, 20%
- Foundational Concept 3, 25%

Scientific Inquiry and Reasoning Skill:

- Skill 1, 35%
- Skill 2, 45%
- Skill 3, 10%
- Skill 4, 10%

Biological and Biochemical Foundations of Living Systems Framework of Foundational Concepts and Content Categories

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

The content categories for this foundational concept include:

1A. Structure and function of proteins and their constituent amino acids.

1B. Transmission of genetic information from the gene to the protein.

1C. Transmission of heritable information from generation to generation and the processes that increase genetic diversity.

1D. Principles of bioenergetics and fuel molecule metabolism.

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

The content categories for this foundational concept include:

2A. Assemblies of molecules, cells, and groups of cells within single cellular and multicellular organisms.

2B. The structure, growth, physiology, and genetics of prokaryotes and viruses.

2C. Processes of cell division, differentiation, and specialization.

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

The content categories for this foundational concept include:

3A. Structure and functions of the nervous and endocrine systems and ways these systems coordinate the organ systems.

3B. Structure and integrative functions of the main organ systems.

How Foundational Concepts and Content Categories Fit Together

The MCAT exam asks you to solve problems by combining your knowledge of concepts with your scientific inquiry and reasoning skills. The figure below illustrates how foundational concepts, content categories, and scientific inquiry and reasoning skills intersect when test questions are written.

	Foundational Concept 1			**Foundational Concept 2**		
Skill	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.

Understanding the Foundational Concepts and Content Categories in the Biological and Biochemical Foundations of Living Systems Section

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

EXCERPT FROM BIOLOGICAL AND BIOCHEMICAL FOUNDATONS OF LIVING SYSTEMS OUTLINE

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

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

The abbreviations in parentheses indicate the courses 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

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

Using the excerpt above as an example:

- You are responsible for learning about the topic Metabolism of Fatty Acids and Proteins at the level taught in a typical two-semester introductory biology sequence *and* in a typical first-semester biochemistry course.

- You are responsible for learning about the subtopics Anabolism of fats, Nontemplate synthesis: biosynthesis of lipids and polysaccharides, and Metabolism of proteins *only* at the levels taught in a typical two-semester sequence of introductory biology.
- You are responsible for learning about the subtopics Description of fatty acids and Ketone bodies *only* at the levels taught in a typical first-semester biochemistry course.

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

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.

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 cells. The proper functioning of a living system depends on the many components acting harmoniously in response to a constantly changing environment. Biomolecules are constantly formed or degraded in response to the perceived needs of the organism.

Content Categories

- *Category 1A* focuses on the structural and functional complexity of proteins, which is derived from their component amino acids, the sequence in which the amino acids are covalently bonded, and the three-dimensional structures the proteins adopt in an aqueous environment.
- *Category 1B* focuses on the molecular mechanisms responsible for the transfer of sequence-specific biological information between biopolymers that ultimately result 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 the processes that take place within a living system.

With these building blocks, medical students will be able to learn how the major biochemical, genetic, and molecular functions of the cell support health and lead disease.

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 the whole assembly interacts with water.	**Amino Acids (BC, OC)** ▪ Description ○ Absolute configuration at the α position ○ Amino acids as dipolar ions ○ Classifications ▪ Acidic or basic ▪ Hydrophobic or hydrophilic ▪ Reactions ○ Sulfur linkage for cysteine and cystine ○ Peptide linkage: polypeptides and proteins ○ Hydrolysis

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 that 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.
	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
	
	Nonenzymatic Protein Function (BIO, BC)
	
	▪ Binding (BC)
	▪ Immune system
	▪ Motors
	
	Enzyme Structure and Function (BIO, BC)
	
	▪ Function of enzymes in catalyzing biological reactions
	▪ Enzyme classification by reaction type
	▪ Reduction of activation energy
	▪ Substrates and enzyme specificity
	▪ Active Site Model
	▪ Induced-Fit Model
	▪ Mechanism of catalysis
	  ○ Cofactors
	  ○ Coenzymes
	  ○ Water-soluble vitamins
	▪ Effects of local conditions on enzyme activity
	
	Control of Enzyme Activity (BIO, BC)
	
	▪ Kinetics
	  ○ General (catalysis)
	  ○ Michaelis-Menten
	  ○ Cooperativity

	▪ Feedback regulation
	▪ Inhibition — types
	  ○ Competitive
	  ○ Noncompetitive
	  ○ Mixed (BC)
	  ○ Uncompetitive (BC)
	▪ Regulatory enzymes
	  ○ Allosteric enzymes
	  ○ Covalently modified enzymes
	  ○ Zymogen

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
	Nucleic Acid Structure and Function (BIO, BC)
	
	▪ Description
	▪ Nucleotides and nucleosides
	  ○ Sugar phosphate backbone
	  ○ Pyrimidine, purine residues
	▪ Deoxyribonucleic acid (DNA): double helix, Watson-Crick model of DNA structure
	▪ Base pairing specificity: A with T, G with C
	▪ Function in transmission of genetic information (BIO)
	▪ DNA denaturation, reannealing, hybridization
	
	DNA Replication (BIO)
	
	▪ Mechanism of replication: separation of strands, specific coupling of free nucleic acids
	▪ Semiconservative 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

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 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 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 category, however, are those that take advantage of the complementary structure of double-stranded DNA molecules to synthesize, sequence, and amplify them and to analyze and identify unknown polynucleotide sequences. Included within this treatment of biotechnology are those practical applications that 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.

- 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 RNAs (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 noncoding 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
1C: Transmission of heritable information from generation to generation and the processes that increase genetic diversity The information necessary to direct life functions is contained within discrete nucleotide sequences transmitted from generation to generation by mechanisms that, by nature of their various processes, provide the raw materials for evolution by increasing genetic diversity. Specific sequences of deoxyribonucleic acids store and transfer the heritable information necessary for the continuation of life from one generation to the next. These sequences, called *genes* — being part of longer DNA molecules — are	**Evidence That DNA Is Genetic Material (BIO)** **Mendelian Concepts (BIO)** ▪ Phenotype and genotype ▪ Gene ▪ Locus ▪ Allele: single and multiple ▪ Homozygosity and heterozygosity ▪ Wild-type ▪ Recessiveness ▪ Complete dominance ▪ Co-dominance ▪ Incomplete dominance, leakage, penetrance, expressivity ▪ Hybridization: viability

organized, along with various proteins, into biomolecular assemblies called *chromosomes*.

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

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

The content in this category covers the mechanisms by which heritable information is transmitted from generation to generation and the evolutionary processes that generate and act on genetic variation.

- Gene pool

Meiosis and Other Factors Affecting Genetic Variability (BIO)

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

Analytic Methods (BIO)

- Hardy-Weinberg Principle
- Testcross (Backcross; concepts of parental, F1, and F2 generations)
- Gene mapping: crossover frequencies
- Biometry: statistical methods

	Evolution (BIO) ▪ Natural selection ○ Fitness concept ○ Selection by differential reproduction ○ Concepts of natural and group selection ○ Evolutionary success as increase in percentage 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
1D: Principles of bioenergetics and fuel molecule metabolism Living things harness energy from fuel molecules in a controlled manner that sustains all the processes responsible for maintaining life. Cell maintenance and growth is energetically costly. Cells harness the energy stored in fuel molecules, such as carbohydrates and fatty acids, and convert it into smaller units of chemical potential known as *adenosine triphosphate* (ATP). The hydrolysis of ATP provides a ready source of energy for cells that can be coupled to other chemical processes that 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,	**Principles of Bioenergetics (BC, GC)** ▪ Bioenergetics/thermodynamics ▪ Free energy/K_{eq} ○ Equilibrium constant ○ Relationship of the equilibrium constant and $\Delta G°$ ▪ Concentration ○ Le Châtelier's Principle ▪ Endothermic and exothermic reactions ▪ Free energy: G ▪ Spontaneous reactions and $\Delta G°$ ▪ Phosphoryl group transfers and ATP ○ ATP hydrolysis $\Delta G << 0$ ○ ATP group transfers ▪ Biological oxidation-reduction ○ Half-reactions ○ Soluble electron carriers ○ Flavoproteins

regulation of these metabolic pathways, fuel molecule mobilization, transport, and storage are covered.	**Carbohydrates (BC, OC)**
	▪ Description
	  ○ Nomenclature and classification, common names
	  ○ Absolute configuration
	  ○ Cyclic structure and conformations of hexoses
	  ○ Epimers and anomers
	▪ Hydrolysis of the glycoside linkage
	▪ Monosaccharides
	▪ Disaccharides
	▪ Polysaccharides
	
	Glycolysis, Gluconeogenesis, and the Pentose Phosphate Pathway (BIO, BC)
	▪ Glycolysis (aerobic), substrates and products
	  ○ Feeder pathways: glycogen, starch metabolism
	▪ Fermentation (anaerobic glycolysis)
	▪ Gluconeogenesis (BC)
	▪ Pentose phosphate pathway (BC)
	▪ Net molecular and energetic results of respiration processes
	
	Principles of Metabolic Regulation (BC)
	▪ Regulation of metabolic pathways (BIO, BC)
	  ○ Maintenance of a dynamic steady state
	▪ Regulation of glycolysis and gluconeogenesis
	▪ Metabolism of glycogen
	▪ Regulation of glycogen synthesis and breakdown
	  ○ Allosteric and hormonal control
	▪ Analysis of metabolic control
	
	Citric Acid Cycle (BIO, BC)
	▪ Acetyl-CoA production (BC)
	▪ Reactions of the cycle, substrates and products
	▪ Regulation of the cycle
	▪ Net molecular and energetic results of respiration processes

	Metabolism of Fatty Acids and Proteins (BIO, BC)
	
	▪ Description of fatty acids (BC)
	▪ Digestion, mobilization, and transport of fats
	▪ Oxidation of fatty acids
	  ○ Saturated fats
	  ○ Unsaturated fats
	▪ Ketone bodies (BC)
	▪ Anabolism of fats (BIO)
	▪ Nontemplate synthesis: biosynthesis of lipids and polysaccharides (BIO)
	▪ Metabolism of proteins (BIO)
	
	Oxidative Phosphorylation (BIO, BC)
	
	▪ Electron transport chain and oxidative phosphorylation, substrates and products, general features of the pathway
	▪ Electron transfer in mitochondria
	  ○ NADH, NADPH
	  ○ Flavoproteins
	  ○ Cytochromes
	▪ ATP synthase, chemiosmotic coupling
	  ○ Proton motive force
	▪ Net molecular and energetic results of respiration processes
	▪ Regulation of oxidative phosphorylation
	▪ Mitochondria, apoptosis, oxidative stress (BC)
	
	Hormonal Regulation and Integration of Metabolism (BC)
	
	▪ Higher-level integration of hormone structure and function
	▪ Tissue-specific metabolism
	▪ Hormonal regulation of fuel metabolism
	▪ Obesity and regulation of body mass

Biological and Biochemical Foundations of Living Systems

Foundational Concept 2

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

Cells are the basic unit of structure in all living things. Mechanisms of cell division provide not only for the growth and maintenance of organisms, but also for the continuation of the species through asexual and sexual reproduction. The unique microenvironment 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 organized into specialized structures with specialized functions — both of which result from the unique properties of the cells' component molecules.

Content Categories

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

With these building blocks, medical students will be able to learn how cells grow and integrate to form tissues and organs that carry out essential biochemical and physiological functions.

2A: Assemblies of molecules, cells, and groups of cells within single cellular and multicellular organisms
 	
The processes necessary to maintain life are executed by assemblies of molecules, cells, and groups of cells, all of which are organized into highly specific structures as determined by the unique properties of their component molecules. The processes necessary to maintain life require that cells create and maintain internal environments within the cytoplasm and
	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

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 identifying tissues or recent events in the cell's history for purposes of recognition of "self" versus foreign molecules.

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

- Solute transport across membranes
  - Thermodynamic considerations
  - Osmosis
    - Colligative properties; osmotic pressure (GC)
  - Passive transport
  - Active transport
    - Sodium/potassium pump
- Membrane channels
- Membrane potential
- Membrane receptors
- Exocytosis and endocytosis
- Intercellular junctions (BIO)
  - Gap junctions
  - Tight junctions
  - Desmosomes

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

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

specialized functions. Epithelial tissue and connective tissue are covered in this category.	▪ 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

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; 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. This happens 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
	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

prokaryotes and the characteristics that distinguish them from eukaryotes. Viruses are also covered here.	▪ 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 o Attachment to host, penetration of cell membrane or cell wall, and entry of viral genetic material o Use of host synthetic mechanism to replicate viral components o 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
2C: Processes of cell division, differentiation, and specialization	**Mitosis (BIO)** ▪ Mitotic process: prophase, metaphase, anaphase, telophase, interphase

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 structures, 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.

- Mitotic structures
  - Centrioles, asters, spindles
  - Chromatids, centromeres, kinetochores
  - Nuclear membrane breakdown and reorganization
  - Mechanisms of chromosome movement
- Phases of cell cycle: G0, G1, S, G2, M
- Growth arrest
- Control of cell cycle
- Loss of cell cycle controls in cancer cells

Biosignaling (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.

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

Content Categories

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

With these building blocks, medical students will be able to learn how the body responds to internal and external stimuli to support homeostasis and the ability to reproduce.

3A: Structure and functions of the nervous and endocrine systems and ways these systems coordinate the organ systems	**Nervous System: Structure and Function (BIO)**
The nervous and endocrine systems work together to detect external and internal signals, transmit and integrate information, and maintain homeostasis. They do all 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 used to facilitate and enhance survival, growth, and reproduction. The nervous system interfaces with	▪ 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

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 changed over time 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.	**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 **Biosignaling (BC)** ▪ Gated ion channels ○ Voltage gated ○ Ligand gated ▪ Receptor enzymes ▪ G protein-coupled receptors **Lipids (BC, OC)** ▪ Description; structure ○ Steroids ○ Terpenes and terpenoids **Endocrine System: Hormones and Their Sources (BIO)** ▪ Function of endocrine system: specific chemical control at cell, tissue, and organ level ▪ Definitions of endocrine gland, hormone

	▪ Major endocrine glands: names, locations, products ▪ Major types of hormones ▪ Neuroendocrinology — relation between neurons and hormonal systems **Endocrine System: Mechanisms of Hormone Action (BIO)** ▪ Cellular mechanisms of hormone action ▪ Transport of hormones: blood supply ▪ Specificity of hormones: target tissue ▪ Integration with nervous system: feedback control ▪ Regulation by second messengers
3B: Structure and integrative functions of the main organ systems Animals use a number of highly organized and integrated organ systems to carry out the necessary functions associated with maintaining life processes. Within the body, no organ system is an island. Interactions and coordination between organ systems allow organisms to engage in the processes necessary to sustain life. For example, the organs and structures of the circulatory system carry out a number of functions, such as transporting: ▪ Nutrients absorbed in the digestive system. ▪ Gases absorbed from the respiratory system and muscle tissue. ▪ Hormones secreted from the endocrine system. ▪ Blood cells, produced in bone marrow, to and from cells in the body to help fight disease. The content in this category covers the structure and function of the major organ systems of the body, including the respiratory, circulatory, lymphatic, immune, digestive, excretory, reproductive, muscle, skeletal, and skin systems. Also covered in this category is the integration of these systems and their control	**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_2 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

and coordination by the endocrine and nervous systems.	▪ 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 ▪ 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 (nonspecific) vs. adaptive (specific) immunity ▪ Adaptive immune system cells ○ T-lymphocytes ○ B-lymphocytes

	▪ Innate immune system cells ○ Macrophages ○ Phagocytes ▪ Tissues ○ Bone marrow ○ Spleen ○ Thymus ○ Lymph nodes ▪ Concept of antigen and antibody ▪ Antigen presentation ▪ Clonal selection ▪ Antigen-antibody recognition ▪ Structure of antibody molecule ▪ Recognition of self vs. nonself, 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_2O, amino acids, glucose, ions ▪ Muscular control: sphincter muscle **Reproductive System (BIO)** ▪ Male and female reproductive structures and their functions o Gonads o Genitalia o Differences between male and female structures ▪ Hormonal control of reproduction o Male and female sexual development o Female reproductive cycle o Pregnancy, parturition, lactation o Integration with nervous control **Muscle System (BIO)** ▪ Important functions o Support: mobility o Peripheral circulatory assistance o Thermoregulation (shivering reflex) ▪ Structure of three basic muscle types: striated, smooth, cardiac ▪ Muscle structure and control of contraction o T-tubule system o Contractile apparatus o Sarcoplasmic reticulum o Fiber type o Contractile velocity of different muscle types ▪ Regulation of cardiac muscle contraction ▪ Oxygen debt: fatigue ▪ Nervous control o Motor neurons o Neuromuscular junction, motor end plates o Sympathetic and parasympathetic innervation o Voluntary and involuntary muscles

	Specialized Cell — Muscle Cell (BIO) ▪ Structural characteristics of striated, smooth, and cardiac muscle ▪ Abundant mitochondria in red muscle cells: ATP source ▪ Organization of contractile elements: actin and myosin filaments, crossbridges, sliding filament model ▪ Sarcomeres: "I" and "A" bands, "M" and "Z" lines, "H" zone ▪ Presence of troponin and tropomyosin ▪ Calcium regulation of contraction **Skeletal System (BIO)** ▪ Functions ○ Structural rigidity and support ○ Calcium storage ○ Physical protection ▪ Skeletal structure ○ Specialization of bone types, structures ○ Joint structures ○ Endoskeleton vs. exoskeleton ▪ Bone structure ○ Calcium-protein matrix ○ Cellular composition of bone ▪ Cartilage: structure and function ▪ Ligaments, tendons ▪ Endocrine control **Skin System (BIO)** ▪ Structure ○ Layer differentiation, cell types ○ Relative impermeability to water ▪ Functions in homeostasis and osmoregulation ▪ Functions in thermoregulation ○ Hair, erectile musculature ○ Fat layer for insulation ○ Sweat glands, location in dermis

	○ Vasoconstriction and vasodilation in surface capillaries ▪ Physical protection ○ Nails, calluses, hair ○ Protection against abrasion, disease organisms ▪ Hormonal control: sweating, vasodilation, and vasoconstriction

Chemical and Physical Foundations of Biological Systems

What Will the Chemical and Physical Foundations of Biological Systems Section Test?

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

This section is 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 molecular biology topics at the level taught in many colleges and universities in introductory biology sequences and first-semester biochemistry courses.
- Test basic research methods and statistics concepts described by many baccalaureate faculty as important to success in introductory science courses.
- Require you to demonstrate your scientific inquiry and reasoning, research methods, and statistics skills as applied to the natural sciences.

Test Section	Number of Questions	Time
Chemical and Physical Foundations of Biological Systems	59 (note that questions are a combination of passage-based and discrete questions)	95 minutes

Scientific Inquiry and Reasoning Skills

As a reminder, the scientific inquiry and reasoning skills you will be asked to demonstrate on this section of the exam are:

Knowledge of Scientific Concepts and Principles

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

Scientific Reasoning and Problem-Solving

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

Reasoning About the Design and Execution of Research

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

Data-Based and Statistical Reasoning

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

General Mathematical Concepts and Techniques

It's important for you to know that questions on the natural, behavioral, and social sciences sections will ask you to use certain mathematical concepts and techniques. As the descriptions of the scientific inquiry and reasoning skills suggest, some questions will ask you to analyze and manipulate scientific data to show you can:

- Recognize and interpret linear, semilog, and log-log scales and calculate slopes from data found in figures, graphs, and tables.
- Demonstrate a general understanding of significant digits and the use of reasonable numerical estimates in performing measurements and calculations.
- Use metric units, including converting units within the metric system and between metric and English units (conversion factors will be provided when needed), and dimensional analysis (using units to balance equations).
- Perform arithmetic calculations involving the following: probability, proportion, ratio, percentage, and square-root estimations.
- Demonstrate a general understanding (Algebra II-level) of exponentials and logarithms (natural and base 10), scientific notation, and solving simultaneous equations.
- Demonstrate a general understanding of the following trigonometric concepts: definitions of basic (sine, cosine, tangent) and inverse ($\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$) functions; sin and cos values of 0°, 90°, and 180°; relationships between the lengths of sides of right triangles containing angles of 30°, 45°, and 60°.
- Demonstrate a general understanding of vector addition and subtraction and the right-hand rule (knowledge of dot and cross products is not required)

Resource

You will have access to the periodic table shown while answering questions in this section of the exam.

Periodic Table of the Elements

1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac† (227)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)

*	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

Chemical and Physical Foundations of Biological Systems Distribution of Questions by Discipline, Foundational Concept, and Scientific Inquiry and Reasoning Skill

You may wonder how much chemistry you'll see on this section of the MCAT exam, how many questions you'll get about a particular foundational concept, or how the scientific inquiry and reasoning skills will be distributed on your exam. The questions you see are likely to be distributed in the ways described below. These are the approximate percentages of questions you'll see on a test for each discipline, foundational concept, and scientific inquiry and reasoning skill. (These percentages have been approximated to the nearest 5% and will vary from one test to another for a variety of reasons, including, but not limited to, controlling for question difficulty, using groups of questions that depend on a single passage, and using unscored field-test questions on each test form.)

Discipline:

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

Foundational Concept:

- Foundational Concept 4, 40%
- Foundational Concept 5, 60%

Scientific Inquiry and Reasoning Skill:

- Skill 1, 35%
- Skill 2, 45%
- Skill 3, 10%
- Skill 4, 10%

Chemical and Physical Foundations of Biological Systems Framework of Foundational Concepts and Content Categories

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 are:

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 are:

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.

How Foundational Concepts and Content Categories Fit Together

The MCAT exam asks you to solve problems by combining your knowledge of concepts with your scientific inquiry and reasoning skills. The figure below illustrates how foundational concepts, content categories, and scientific inquiry and reasoning skills intersect when test questions are written.

	Foundational Concept 1			Foundational Concept 2		
Skill	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.

Understanding the Foundational Concepts and Content Categories in the Chemical and Physical Foundations of Biological Systems Outline

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

EXCERPT FROM THE CHEMICAL AND PHYSICAL FOUNDATIONS OF BIOLOGICAL SYSTEMS OUTLINE

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

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

The abbreviations 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 exam, you will be responsible for learning the topics and associated subtopics at the levels taught at many colleges and universities 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 taught in a typical two-semester organic chemistry sequence *and* in a typical first-semester biochemistry course.
- You are responsible for learning about the subtopic Separation and purifications of peptides and proteins (and sub-subtopics) *only* at the level taught in a first-semester biochemistry course.
- You are responsible for learning about the subtopic Racemic mixtures, separation of enantiomers *only* at the level 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 described in this chapter may be covered in courses with titles that are different from those listed here. Your prehealth advisor and faculty are important resources for your questions about course content.

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.

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

Content Categories

- *Category 4A* focuses on motion and its causes and various forms of energy and their interconversions.
- *Category 4B* focuses on the behavior of fluids, which is relevant to the functioning of the pulmonary and circulatory systems.
- *Category 4C* emphasizes the nature of electrical currents and voltages, how energy can be converted into electrical forms that can be used to perform chemical transformations or work, and how electrical impulses can be transmitted over long distances in the nervous system.
- *Category 4D* focuses on the properties of light and sound, 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 subatomic 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 use core principles of physics to learn about the physiological functions of the respiratory, cardiovascular, and neurological systems in health and disease.

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 on 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	**Translational Motion (PHY)** ▪ Units and dimensions ▪ Vectors, components ▪ Vector addition ▪ Speed, velocity (average and instantaneous) ▪ Acceleration **Force (PHY)** ▪ Newton's First Law, inertia ▪ Newton's Second Law ($F = ma$)

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.	▪ Newton's Third Law, forces equal and opposite ▪ Friction, static and kinetic ▪ Center of mass **Equilibrium (PHY)** ▪ Vector analysis of forces acting on a point object ▪ Torques, lever arms **Work (PHY)** ▪ Work done by a constant force: $W = Fd\cos\vartheta$ ▪ Mechanical advantage ▪ Work Kinetic Energy Theorem ▪ Conservative forces **Energy of Point Object Systems (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 ▪ Power, units **Periodic Motion (PHY)** ▪ Amplitude, frequency, phase ▪ Transverse and longitudinal waves: wavelength and propagation speed
4B: Importance of fluids for the circulation of blood, gas movement, and gas exchange Fluids are featured in several physiologically important processes, including the circulation of blood, gas movement into and out of the lungs, and gas exchange with the blood. The energetic requirements of fluid dynamics can be modeled using physical equations. A thorough understanding of fluids is necessary to understand the origins of numerous forms of disease.	**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 ($A \cdot v$ = constant) ▪ Concept of turbulence at high velocities ▪ Surface tension ▪ Bernoulli's equation

The content in this category covers hydrostatic pressure, fluid flow rates, viscosity, the Kinetic Molecular Theory of Gases, and the Ideal Gas Law.	▪ Venturi effect, pitot tube **Circulatory System (BIO)** ▪ Arterial and venous systems; pressure and flow characteristics **Gas Phase (GC, PHY)** ▪ Absolute temperature, K, Kelvin scale ▪ Pressure, simple mercury barometer ▪ Molar volume at 0°C and 1 atm = 22.4 L/mol ▪ Ideal gas ○ Definition ○ Ideal Gas Law: $PV = nRT$ ○ Boyle's Law: PV = constant ○ Charles' Law: V/T = constant ○ Avogadro's Law: V/n = constant ▪ Kinetic Molecular Theory of Gases ○ Heat capacity at constant volume and at constant pressure (PHY) ○ Boltzmann's Constant (PHY) ▪ Deviation of real gas behavior from Ideal Gas Law ○ Qualitative ○ Quantitative (Van der Waals' Equation) ▪ Partial pressure, mole fraction ▪ Dalton's Law relating partial pressure to composition
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	**Electrostatics (PHY)** ▪ Charge, conductors, charge conservation ▪ Insulators ▪ Coulomb's Law ▪ Electric field E ○ Field lines ○ Field due to charge distribution ▪ Electrostatic energy, electric potential at a point in space

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.	**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: $\rho = R \bullet A/L$ ▪ Capacitance ○ Parallel plate capacitor ○ Energy of charged capacitor ○ Capacitors in series ○ Capacitors in parallel ○ Dielectrics ▪ Conductivity ○ Metallic ○ Electrolytic ▪ Meters **Magnetism (PHY)** ▪ Definition of magnetic field B ▪ Motion of charged particles in magnetic fields; Lorentz force **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
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 used 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 used in ultrasound imaging. This noninvasive 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.	**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's double-slit experiment ▪ Thin films, diffraction grating, single-slit diffraction ▪ Other diffraction phenomena, X-ray diffraction ▪ Polarization of light: linear and circular ▪ Properties of electromagnetic radiation ○ Velocity equals constant *c*, in vacuo ○ Electromagnetic radiation consists of perpendicularly oscillating electric and magnetic fields; direction of propagation is perpendicular to both ▪ Classification of electromagnetic spectrum, photon energy $E = hf$ ▪ Visual spectrum, color

	Molecular Structure and Absorption Spectra (OC) ▪ Infrared region ○ Intramolecular vibrations and rotations ○ Recognizing common characteristic group absorptions, fingerprint region ▪ Visible region (GC) ○ Absorption in visible region gives complementary color (e.g., carotene) ○ Effect of structural changes on absorption (e.g., indicators) ▪ Ultraviolet region ○ π-Electron and nonbonding electron transitions ○ Conjugated systems ▪ NMR spectroscopy ○ Protons in a magnetic field; equivalent protons ○ Spin-spin splitting **Geometrical Optics (PHY)** ▪ Reflection from plane surface: angle of incidence equals angle of reflection ▪ Refraction, refractive index n; Snell's law: $n_1 \sin \vartheta_1 = n_2 \sin \vartheta_2$ ▪ 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

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 they 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 of 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.

Atomic Nucleus (PHY, GC)

- Atomic number, atomic weight
- Neutrons, protons, isotopes
- Nuclear forces, binding energy
- Radioactive decay
  - α, β, γ decay
  - Half-life, exponential decay, semi-log plots
- Mass spectrometer
- Mass spectroscopy

Electronic Structure (PHY, GC)

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

The Periodic Table — Classification of Elements Into Groups by Electronic Structure (GC)

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

	The Periodic Table — Variations of Chemical Properties with Group and Row (GC) ▪ Valence electrons ▪ First and second ionization energy ○ Definition ○ Prediction from electronic structure for elements in different groups or rows ▪ Electron affinity ○ Definition ○ Variation with group and row ▪ Electronegativity ○ Definition ○ Comparative values for some representative elements and important groups ▪ Electron shells and the sizes of atoms ▪ Electron shells and the sizes of ions **Stoichiometry (GC)** ▪ Molecular weight ▪ Empirical vs. molecular formula ▪ Metric units commonly used in the context of chemistry ▪ Description of composition by percent mass ▪ Mole concept, Avogadro's number N_A ▪ Definition of density ▪ Oxidation number ○ Common oxidizing and reducing agents ○ Disproportionation reactions ▪ Description of reactions by chemical equations ○ Conventions for writing chemical equations ○ Balancing equations, including redox equations ○ Limiting reactants ○ Theoretical yields

Chemical and Physical Foundations of Biological Systems

Foundational Concept 5

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

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

5A: Unique nature of water and its solutions

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.

Acid-Base Equilibria (GC, BC)

- Brønsted-Lowry definition of acid, base
- Ionization of water
  - K_w, its approximate value ($K_w = [H^+][OH^-] = 10^{-14}$ at 25°C, 1 atm)
  - Definition of pH: pH of pure water
- Conjugate acids and bases (e.g., NH_4^+ and 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: pK_a, pK_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., NH_4^+ ammonium, PO_4^{3-} phosphate, 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

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.
	Covalent Bond (GC)
	
	▪ Lewis electron dot formulas
	  ○ Resonance structures
	  ○ Formal charge
	  ○ Lewis acids and bases
	▪ Partial ionic character
	  ○ Role of electronegativity in determining charge distribution
	  ○ Dipole moment
	▪ σ and π 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., NH_3, H_2O, 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
	  ○ Effect on bond length and bond energies
	  ○ Rigidity in molecular structure

	▪ Stereochemistry of covalently bonded molecules (OC) ○ Isomers ▪ Structural isomers ▪ Stereoisomers (e.g., diastereomers, enantiomers, *cis-trans* isomers) ▪ Conformational isomers ○ Polarization of light, specific rotation ○ Absolute and relative configuration ▪ Conventions for writing *R* and *S* forms ▪ Conventions for writing *E* and *Z* forms **Liquid Phase — Intermolecular Forces (GC)** ▪ Hydrogen bonding ▪ Dipole Interactions ▪ Van der Waals' Forces (London dispersion forces)
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 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.	**Separations and Purifications (OC, BC)** ▪ Extraction: distribution of solute between two immiscible solvents ▪ Distillation ▪ Chromatography: basic principles involved in separation process ○ Column chromatography ▪ Gas-liquid chromatography ▪ High-pressure liquid chromatography ○ Paper chromatography ○ Thin-layer chromatography ▪ Separation and purification of peptides and proteins (BC) ○ Electrophoresis ○ Quantitative analysis ○ Chromatography ▪ Size-exclusion ▪ Ion-exchange ▪ Affinity ▪ Racemic mixtures, separation of enantiomers (OC)

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.

Nucleotides and Nucleic Acids (BC, BIO)

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

Amino Acids, Peptides, Proteins (OC, BC)

- Amino acids: description
  - Absolute configuration at the α position
  - Dipolar ions
  - Classification
    - Acidic or basic
    - Hydrophilic or hydrophobic
  - Synthesis of α-amino acids (OC)
    - Strecker Synthesis
    - Gabriel Synthesis
- Peptides and proteins: reactions
  - Sulfur linkage for cysteine and cystine
  - Peptide linkage: polypeptides and proteins
  - Hydrolysis (BC)
- General principles
  - Primary structure of proteins
  - Secondary structure of proteins
  - Tertiary structure of proteins
  - Isoelectric point

The Three-Dimensional Protein Structure (BC)

- Conformational stability
  - Hydrophobic interactions
  - Solvation layer (entropy)
- Quaternary structure
- Denaturing and folding

	Nonenzymatic Protein Function (BC) ▪ Binding ▪ Immune system ▪ Motor **Lipids (BC, OC)** ▪ Description, types ○ Storage ▪ Triacyl glycerols ▪ Free fatty acids: saponification ○ Structural ▪ Phospholipids and phosphatids ▪ Sphingolipids (BC) ▪ Waxes ○ Signals, cofactors ▪ Fat-soluble vitamins ▪ Steroids ▪ Prostaglandins (BC) **Carbohydrates (OC)** ▪ Description ○ Nomenclature and classification, common names ○ Absolute configuration ○ Cyclic structure and conformations of hexoses ○ Epimers and anomers ▪ Hydrolysis of the glycoside linkage ▪ Keto-enol tautomerism of monosaccharides ▪ Disaccharides (BC) ▪ Polysaccharides (BC) **Aldehydes and Ketones (OC)** ▪ Description ○ Nomenclature ○ Physical properties ▪ Important reactions ○ Nucleophilic addition reactions at C=O bond ▪ Acetal, hemiacetal ▪ Imine, enamine ▪ Hydride reagents

	▪ Cyanohydrin ○ Oxidation of aldehydes ○ Reactions at adjacent positions: enolate chemistry ▪ Keto-enol tautomerism (α-racemization) ▪ Aldol condensation, retro-aldol ▪ Kinetic vs. thermodynamic enolate ▪ General principles ○ Effect of substituents on reactivity of C=O; steric hindrance ○ Acidity of α-H; carbanions **Alcohols (OC)** ▪ Description ○ Nomenclature ○ Physical properties (acidity, hydrogen bonding) ▪ Important reactions ○ Oxidation ○ Substitution reactions: S_N1 or S_N2 ○ Protection of alcohols ○ Preparation of mesylates and tosylates **Carboxylic Acids (OC)** ▪ Description ○ Nomenclature ○ Physical properties ▪ Important reactions ○ Carboxyl group reactions ▪ Amides (and lactam), esters (and lactone), anhydride formation ▪ Reduction ▪ Decarboxylation ○ Reactions at 2-position, substitution **Acid Derivatives (Anhydrides, Amides, Esters) (OC)** ▪ Description ○ Nomenclature ○ Physical properties ▪ Important reactions ○ Nucleophilic substitution

	○ Transesterification ○ Hydrolysis of amides ▪ General principles ○ Relative reactivity of acid derivatives ○ Steric effects ○ Electronic effects ○ Strain (e.g., β-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
5E: Principles of chemical thermodynamics and kinetics The processes that occur in living systems are dynamic, and they follow the principles of chemical thermodynamics and kinetics. The position of chemical equilibrium is dictated by the relative energies of products and reactants. The rate at which chemical equilibrium is attained is dictated by a variety of factors: concentration of reactants, temperature, and the amount of catalyst (if any). Biological systems have evolved to harness energy and use it in very efficient ways to support all processes of life, including homeostasis and anabolism. Biological catalysts, known as *enzymes*, have evolved that allow all 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.	**Enzymes (BC, BIO)** ▪ Classification by reaction type ▪ Mechanism ○ Substrates and enzyme specificity ○ Active-site model ○ Induced-fit model ○ Cofactors, coenzymes, and vitamins ▪ Kinetics ○ General (catalysis) ○ Michaelis-Menten ○ Cooperativity ○ Effects of local conditions on enzyme activity ▪ Inhibition ▪ Regulatory enzymes ○ Allosteric ○ Covalently modified **Principles of Bioenergetics (BC)** ▪ Bioenergetics/thermodynamics ○ Free energy, K_{eq} ○ Concentration ▪ Phosphorylation/ATP ○ ATP hydrolysis $\Delta G << 0$

	○ ATP group transfers ▪ Biological oxidation-reduction ○ Half-reactions ○ Soluble electron carriers ○ Flavoproteins **Energy Changes in Chemical Reactions — Thermochemistry, Thermodynamics (GC, PHY)** ▪ Thermodynamic system – state function ▪ Zeroth Law – concept of temperature ▪ First Law – conservation of energy in thermodynamic processes ▪ PV diagram: work done = area under or enclosed by curve (PHY) ▪ 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 ΔG° (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 on concentration of reactants ○ Rate law, rate constant ○ Reaction order

	▪ Rate-determining step ▪ Dependence of reaction rate on temperature ○ Activation energy ▪ Activated complex or transition state ▪ Interpretation of energy profiles showing energies of reactants, products, activation energy, and Δ*H* for the reaction ○ Use of the Arrhenius Equation ▪ Kinetic control vs. thermodynamic control of a reaction ▪ Catalysts ▪ Equilibrium in reversible chemical reactions ○ Law of Mass Action ○ Equilibrium Constant ○ Application of Le Châtelier's Principle ▪ Relationship of the equilibrium constant and Δ*G*°

Psychological, Social, and Biological Foundations of Behavior

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 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 an increasingly 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.

This section is designed to:

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

Test Section	Number of Questions	Time
Psychological, Social, and Biological Foundations of Behavior	59 (note that questions are a combination of passage-based and discrete questions)	95 minutes

Scientific Inquiry and Reasoning Skills

As a reminder, the scientific inquiry and reasoning skills you will be asked to demonstrate on this section of the exam are:

Knowledge of Scientific Concepts and Principles

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

Scientific Reasoning and Problem-Solving

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

Reasoning About the Design and Execution of Research

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

Data-Based and Statistical Reasoning

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

General Mathematical Concepts and Techniques

It's important for you to know that questions on the natural, behavioral, and social sciences sections will ask you to use certain mathematical concepts and techniques. As the descriptions of the scientific inquiry and reasoning skills suggest, some questions will ask you to analyze and manipulate scientific data to show you can:

- Recognize and interpret linear, semilog, and log-log scales and calculate slopes from data found in figures, graphs, and tables.
- Demonstrate a general understanding of significant digits and the use of reasonable numerical estimates in performing measurements and calculations.
- Use metric units, including converting units within the metric system and between metric and English units (conversion factors will be provided when needed), and dimensional analysis (using units to balance equations).
- Perform arithmetic calculations involving the following: probability, proportion, ratio, percentage, and square-root estimations.
- Demonstrate a general understanding (Algebra II-level) of exponentials and logarithms (natural and base 10), scientific notation, and solving simultaneous equations.
- Demonstrate a general understanding of the following trigonometric concepts: definitions of basic (sine, cosine, tangent) and inverse ($\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$) functions; sin and cos values of 0°, 90°, and 180°; relationships between the lengths of sides of right triangles containing angles of 30°, 45°, and 60°.
- Demonstrate a general understanding of vector addition and subtraction and the right-hand rule (knowledge of dot and cross products is not required)

Note also that an understanding of calculus is *not* required, and a periodic table will be provided during the exam.

Psychological, Social, and Biological Foundations of Behavior Distribution of Questions by Discipline, Foundational Concept, and Scientific Inquiry and Reasoning Skill

You may wonder how much psychology, sociology, and biology you'll see on this section of the MCAT exam, how many questions you'll get about a particular foundational concept, or how the scientific inquiry and reasoning skills will be distributed on your exam. The questions you see are likely to be distributed in the ways described below. These are the approximate percentages of questions you'll see on a test for each discipline, foundational concept, and scientific inquiry and reasoning skill.*

* Please note that about 5% of this test section will include psychology questions that are biologically relevant. This is in addition to the discipline target of 5% for introductory biology specified for this section.

(These percentages have been approximated to the nearest 5% and will vary from one test to another for a variety of reasons, including, but not limited to, controlling for question difficulty, using groups of questions that depend on a single passage, and using unscored field-test questions on each test form.)

Discipline:

- Introductory psychology, 65%
- Introductory sociology, 30%
- Introductory biology, 5%

Foundational Concept:

- Foundational Concept 6, 25%
- Foundational Concept 7, 35%
- Foundational Concept 8, 20%
- Foundational Concept 9, 15%
- Foundational Concept 10, 5%

Scientific Inquiry and Reasoning Skill:

- Skill 1, 35%
- Skill 2, 45%
- Skill 3, 10%
- Skill 4: 10%

Psychological, Social, and Biological Foundations of Behavior Framework of Foundational Concepts and Content Categories

Foundational Concept 6: Biological, psychological, and sociocultural 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 sociocultural factors influence behavior and behavior change.

The content categories for this foundational concept include

7A. Individual influences on behavior

7B. Social processes that influence human behavior

7C. Attitude and behavior change

Foundational Concept 8: Psychological, sociocultural, and biological factors influence the way we think about ourselves and others, as well as how we interact with others.

The content categories for this foundational concept include

8A. Self-identity

8B. Social thinking

8C. Social interactions

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

The content categories for this foundational concept include

9A. Understanding social structure

9B. Demographic characteristics and processes

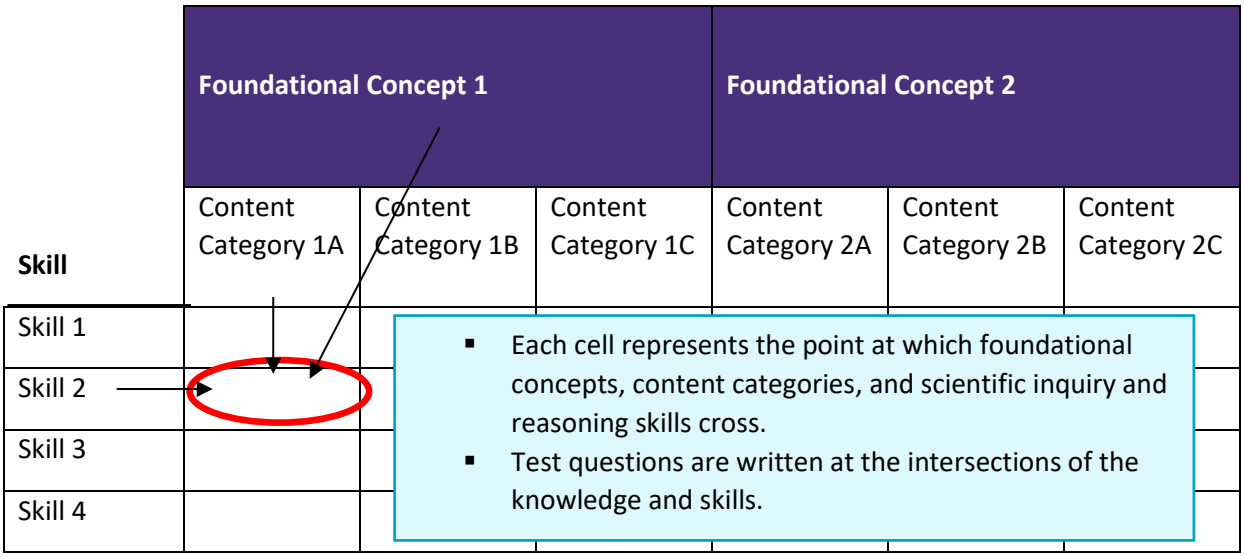
Foundational Concept 10: Social stratification and access to resources influence well-being.

The content category for this foundational concept is

10A. Social inequality

How Foundational Concepts and Content Categories Fit Together

The MCAT exam asks you to solve problems by combining your knowledge of concepts with your scientific inquiry and reasoning skills. The figure below illustrates how foundational concepts, content categories, and scientific inquiry and reasoning skills intersect to create test questions.



Understanding the Foundational Concepts and Content Categories in the Psychological, Social, and Biological Foundations of Behavior Section

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. The same content list is provided to the writers who develop the content of the exam. Here is an excerpt from the content list.

EXCERPT FROM THE PSYCHOLOGICAL, SOCIAL, AND BIOLOGICAL FOUNDATONS OF BEHAVIOR OUTLINE

Self-Presentation and Interacting With Others (PSY, SOC) ← **Topic**

- Expressing and detecting emotion ← **Subtopic**
  - The role of gender in the expression and detection of emotion
  - The role of culture in the expression and detection of emotion
- Presentation of self
  - Impression management
  - Front-stage vs. back-stage self (dramaturgical approach) (SOC)
- Verbal and nonverbal communication
- Animal signals and communication (PSY, BIO)

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

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

In preparing for the MCAT exam, you will be responsible for learning the topics and associated subtopics at the levels 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 taught in a typical introductory psychology course *and* in a typical introductory sociology course.
- You are responsible for learning about the sub-subtopic Front-stage vs. back-stage self (dramaturgical approach) *only* at the level taught in a typical introductory sociology course.

- You are responsible for learning about the subtopic Animal signals and communication at the level taught in a typical introductory psychology course *and* in a typical introductory biology course.

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

Psychological, Social, and Biological Foundations of Behavior

Foundational Concept 6

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

The way 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.

6A: Sensing the environment
 	
Psychological, sociocultural, and biological factors affect how we sense and perceive the world. All sensory processing begins with first detecting a stimulus in the environment through sensory cells, receptors, and biological pathways.
 	
After collecting sensory information, we then interpret and make sense of it. Although sensation and perception are distinct functions, they are both influenced by psychological, social, and biological factors and thus 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 human senses.
	Sensory Processing (PSY, BIO)
	
	▪ Sensation
	  ○ Threshold
	  ○ Weber's Law (PSY)
	  ○ Signal detection theory (PSY)
	  ○ Sensory adaptation
	  ○ Psychophysics
	▪ Sensory receptors
	  ○ Sensory pathways
	  ○ Types of sensory receptors
	
	Vision (PSY, BIO)
	
	▪ Structure and function of the eye
	▪ Visual processing
	  ○ Visual pathways in the brain
	  ○ Parallel processing (PSY)
	  ○ Feature detection (PSY)
	
	Hearing (PSY, BIO)
	
	▪ Structure and function of the ear
	▪ Auditory processing (e.g., auditory pathways in the brain)
	▪ Sensory reception by hair cells
	
	Other Senses (PSY, BIO)
	
	▪ Somatosensation (e.g., pain perception)
	▪ Taste (e.g., taste buds (chemoreceptors) that detect specific chemicals)

	▪ Smell ○ Olfactory cells (chemoreceptors) that detect specific chemicals ○ Pheromones (BIO) ○ Olfactory pathways in the brain (BIO) ▪ Kinesthetic sense (PSY) ▪ Vestibular sense **Perception (PSY)** ▪ Bottom-up/top-down processing ▪ Perceptual organization (e.g., depth, form, motion, constancy) ▪ Gestalt principles
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, sociocultural, and biological influences determine the development and use of these different yet convergent processes. Biological factors underlie the mental processes that create our reality, shape our perception of the world, and influence the way we perceive and react to every aspect of our lives. The content in this category covers critical aspects of cognition — including consciousness, cognitive development, problem-solving and decision-making, intelligence, memory, and language.	**Attention (PSY)** ▪ Selective attention ▪ Divided attention **Cognition (PSY)** ▪ Information-processing model ▪ Cognitive development ○ Piaget's stages of cognitive development ○ Cognitive changes in late adulthood ○ Role of culture in cognitive development ○ Influence of heredity and environment on cognitive development ▪ Biological factors that affect cognition (PSY, BIO) ▪ Problem-solving and decision-making ○ Types of problem-solving ○ Barriers to effective problem-solving ○ Approaches to problem-solving ○ Heuristics and biases (e.g., overconfidence, belief perseverance) ▪ Intellectual functioning ○ Theories of intelligence ○ Influence of heredity and environment on intelligence ○ Variations in intellectual ability

	Consciousness (PSY) ▪ States of consciousness ○ Alertness (PSY, BIO) ○ Sleep ▪ Stages of sleep ▪ Sleep cycles and changes to sleep cycles ▪ Sleep and circadian rhythms (PSY, BIO) ▪ Dreaming ▪ Sleep-wake disorders ○ Hypnosis and meditation ▪ Consciousness-altering drugs ○ Types of consciousness-altering drugs and their effects on the nervous system and behavior ○ Drug addiction and the reward pathway in the brain **Memory (PSY)** ▪ Encoding ○ Process of encoding information ○ Processes that aid in encoding memories ▪ Storage ○ Types of memory storage (e.g., sensory, working, long-term) ○ Semantic networks and spreading activation ▪ Retrieval ○ Recall, recognition, and relearning ○ Retrieval cues ○ The role of emotion in retrieving memories (PSY, BIO) ○ Processes that aid retrieval ▪ Forgetting ○ Aging and memory ○ Memory dysfunctions (e.g., Alzheimer's disease, Korsakoff's syndrome) ○ Decay ○ Interference ○ Memory construction and source monitoring ▪ Changes in synaptic connections underlie memory and learning (PSY, BIO) ○ Neural plasticity

	○ Memory and learning ○ Long-term potentiation **Language (PSY)** ▪ Theories of language development (e.g., learning, nativist, interactionist) ▪ Influence of language on cognition ▪ Brain areas that control language and speech (PSY, BIO)
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, sociocultural, 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, sociocultural, and biological factors. It also addresses stress, stress outcomes, and stress management.	**Emotion (PSY)** ▪ Three components of emotion (i.e., cognitive, physiological, behavioral) ▪ Universal emotions (i.e., 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) ○ Brain regions involved in the generation and experience of emotions ○ The role of the limbic system in emotion ○ Emotion and the autonomic nervous system ○ Physiological markers of emotion (signatures of emotion) **Stress (PSY)** ▪ The nature of stress ○ Appraisal ○ Different types of stressors (e.g., cataclysmic events, personal) ○ Effects of stress on psychological functions

	▪ Stress outcomes, response to stressors ○ Physiological (PSY, BIO) ○ Emotional ○ Behavioral ▪ Managing stress (e.g., exercise, relaxation, spirituality)

Psychological, Social, and Biological Foundations of Behavior

Foundational Concept 7

Biological, psychological, and sociocultural 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, sociocultural, and biological factors 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 social norms, affect behavior.
- *Category 7C* focuses on how learning affects behavior, as well as the role of attitude theories in behavior and behavior change.

With these building blocks, medical students will be able to learn how behavior can either support health or increase risk for disease.

7A: Individual influences on behavior

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

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

Biological Bases of Behavior (PSY, BIO)

- The nervous system
  - Neurons (e.g., the reflex arc)
  - Neurotransmitters
  - Structure and function of the peripheral nervous system
  - Structure and function of the central nervous system
    - The brain
      - Forebrain
      - Midbrain
      - Hindbrain
      - Lateralization of cortical functions
      - Methods used in studying the brain
    - The spinal cord
- Neuronal communication and its influence on behavior (PSY)
- Influence of neurotransmitters on behavior (PSY)

	▪ The endocrine system ○ Components of the endocrine system ○ Effects of the endocrine system on behavior ▪ Behavioral genetics ○ Genes, temperament, and heredity ○ Adaptive value of traits and behaviors ○ Interaction between heredity and environmental influences ▪ Influence of genetic and environmental factors on the development of behaviors ○ Experience and behavior (PSY) ○ Regulatory genes and behavior (BIO) ○ Genetically based behavioral variation in natural populations ▪ Human physiological development (PSY) ○ Prenatal development ○ Motor development ○ Developmental changes in adolescence **Personality (PSY)** ▪ Theories of personality ○ Psychoanalytic perspective ○ Humanistic perspective ○ Trait perspective ○ Social cognitive perspective ○ Biological perspective ○ Behaviorist perspective ▪ Situational approach to explaining behavior **Psychological Disorders (PSY)** ▪ Understanding psychological disorders ○ Biomedical vs. biopsychosocial approaches ○ Classifying psychological disorders ○ Rates of psychological disorders ▪ Types of psychological disorders ○ Anxiety disorders ○ Obsessive-compulsive disorder ○ Trauma- and stressor-related disorders ○ Somatic symptom and related disorders ○ Bipolar and related disorders

	○ Depressive disorders ○ Schizophrenia ○ Dissociative disorders ○ Personality disorders ▪ Biological bases of nervous system disorders (PSY, BIO) ○ Schizophrenia ○ Depression ○ Alzheimer's disease ○ Parkinson's disease ○ Stem cell-based therapy to regenerate neurons in the central nervous system (BIO) **Motivation (PSY)** ▪ Factors that influence motivation ○ Instinct ○ Arousal ○ Drives (e.g., negative-feedback systems) (PSY, BIO) ○ Needs ▪ Theories that explain how motivation affects human behavior ○ Drive reduction theory ○ Incentive theory ○ Other theories (e.g., cognitive, need-based) ▪ Biological and sociocultural motivators that regulate behavior (e.g., hunger, sex drive, substance addiction) **Attitudes (PSY)** ▪ Components of attitudes (i.e., cognitive, affective, behavioral) ▪ The link between attitudes and behavior ○ Processes by which behavior influences attitudes (e.g., foot-in-the door phenomenon, role-playing effects) ○ Processes by which attitudes influence behavior ○ Cognitive dissonance theory

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 and social norms 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 social 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 decision-making processes, social norms, and socialization shape our behavior.
	How the Presence of Others Affects Individual Behavior (PSY)
	
	▪ Social facilitation
	▪ Deindividuation
	▪ Bystander effect
	▪ Social loafing
	▪ Social control (SOC)
	▪ Peer pressure (PSY, SOC)
	▪ Conformity (PSY, SOC)
	▪ Obedience (PSY, SOC)
	
	Group Decision-Making Processes (PSY, SOC)
	
	▪ Group polarization (PSY)
	▪ Groupthink
	
	Normative and Nonnormative Behavior (SOC)
	
	▪ Social norms (PSY, SOC)
	  ○ Sanctions (SOC)
	  ○ Folkways, mores, and taboos (SOC)
	  ○ Anomie (SOC)
	▪ Deviance
	  ○ Perspectives on deviance (e.g., differential association, labeling theory, strain theory)
	▪ Aspects of collective behavior (e.g., fads, mass hysteria, riots)
	
	Socialization (PSY, SOC)
	
	▪ Agents of socialization (e.g., the family, mass media, peers, workplace)

7C: Attitude and behavior change
 	
Learning is a relatively permanent change in behavior brought about by experience. There are a number of different types of learning, which include habituation as well as associative, observational, and social learning.
 	
Although people can learn new behaviors and change their attitudes, psychological, environmental, and
	Habituation and Dishabituation (PSY)
	
	Associative Learning (PSY)
	
	▪ Classical conditioning (PSY, BIO)
	  ○ Neutral, conditioned, and unconditioned stimuli
	  ○ Conditioned and unconditioned response
	  ○ Processes: acquisition, extinction, spontaneous recovery, generalization, discrimination

biological factors influence whether those changes will be short-term or long-term. Understanding how people learn new behaviors and change their attitudes and which conditions affect learning helps us understand behavior and our interactions with others.
 	
The content in this category covers learning and theories of attitude and behavior change. This includes the elaboration likelihood model and social cognitive theory.
	▪ Operant conditioning (PSY, BIO)
	  ○ Processes of shaping and extinction
	  ○ Types of reinforcement: positive, negative, primary, conditional
	  ○ Reinforcement schedules: fixed-ratio, variable-ratio, fixed-interval, variable-interval
	  ○ Punishment
	  ○ Escape and avoidance learning
	▪ The role of cognitive processes in associative learning
	▪ Biological processes that affect associative learning (e.g., biological predispositions, instinctive drift) (PSY, BIO)
	
	Observational Learning (PSY)
	
	▪ Modeling
	▪ Biological processes that affect observational learning
	  ○ Mirror neurons
	  ○ Role of the brain in experiencing vicarious emotions
	▪ Applications of observational learning to explain individual behavior
	
	Theories of Attitude and Behavior Change (PSY)
	
	▪ Elaboration likelihood model
	▪ 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, sociocultural, and biological factors influence the way we think about ourselves and others, as well as how we interact with others.

The connection between how people think about themselves and others is complex and affects social interactions. The interplay between 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 physical, cognitive, and social components of our identity, as well as how these components influence the way we think about and interact 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 interaction.
- *Category 8C* focuses on the actions and processes underlying social interactions.

With these building blocks, medical students will be able to learn how to communicate and collaborate with patients and other members of the health care team.

8A: Self-identity
 	
The self refers to the thoughts and beliefs we have about ourselves. Our notion of the 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 the self develops over time and is shaped by a variety of factors, including society, culture, individuals and groups, and our unique experiences. How we view ourselves influences our perceptions of others and, by extension, our interactions with them.
 	
The content in this category covers the notions of self-concept and identity, along with the role of self-esteem, self-efficacy, and locus of control in the development of self-concept. Identity formation,
	Self-Concept, Self-Identity, and Social Identity (PSY, SOC)
	
	▪ The role of self-esteem, self-efficacy, and locus of control in self-concept and self-identity (PSY)
	▪ Different types of identities (e.g., race/ethnicity, gender, age, sexual orientation, class)
	
	Formation of Identity (PSY, SOC)
	
	▪ Theories of identity development (e.g., gender, moral, psychosexual, social)
	▪ Influence of social factors on identity formation
	  ○ Influence of individuals (e.g., imitation, looking-glass self, role-taking)
	  ○ Influence of groups (e.g., reference group)
	▪ Influence of culture and socialization on identity formation

including developmental stages and the social factors that affect identity formation, is also covered here. Theories are included to provide historical context for the field of identity formation.	

8B: Social thinking
 	
Social thinking refers to the ways 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 develop, including how perceptions of culture and environment affect attributions of behavior. It also covers how our attitudes about different groups — prejudice, stereotypes, stigma, and ethnocentrism — may influence our interactions with group members.
	Attributing Behavior to Persons or Situations (PSY)
	
	▪ Attributional processes (e.g., fundamental attribution error, role of culture in attributions)
	▪ How self-perceptions shape our perceptions of others
	▪ How perceptions of the environment shape our perceptions of others
	
	Prejudice and Bias (PSY, SOC)
	
	▪ Processes that contribute to prejudice
	  ○ Power, prestige, and class (SOC)
	  ○ The role of emotion in prejudice (PSY)
	  ○ The role of cognition in prejudice (PSY)
	▪ Stereotypes
	▪ Stigma (SOC)
	▪ Ethnocentrism (SOC)
	  ○ Ethnocentrism vs. cultural relativism
	
	Processes Related to Stereotypes (PSY)
	
	▪ Self-fulfilling prophecy
	▪ Stereotype threat

8C: Social interactions
 	
Humans are social beings by nature. Though the sentiment is simple, the actions and processes underlying and shaping our social interactions are not.
 	
The changing nature of social interaction is important for understanding the mechanisms and processes through which people interact with each other, both individually and within groups. A variety of factors —
	Elements of Social Interaction (PSY, SOC)
	
	▪ Status (SOC)
	  ○ Types of status (e.g., achieved, ascribed)
	▪ Role
	  ○ Role conflict and role strain (SOC)
	  ○ Role exit (SOC)
	▪ Groups
	  ○ Primary and secondary groups (SOC)
	  ○ In-group vs. out-group

environment, culture, and biology — affect how we present ourselves to others and how we treat others. For example, perceptions of prejudice and stereotypes can lead to acts of discrimination, whereas positive attitudes about others can lead to the provision of help and social support.

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

- Group size (e.g., dyads, triads) (SOC)
- Networks (SOC)
- Organizations (SOC)
  - Formal organization
  - Bureaucracy
    - Characteristics of an ideal bureaucracy
    - Perspectives on bureaucracy (e.g., iron law of oligarchy, McDonaldization)

Self-Presentation and Interacting With Others (PSY, SOC)

- Expressing and detecting emotion
  - The role of gender in the expression and detection of emotion
  - The role of culture in the expression and detection of emotion
- Presentation of self
  - Impression management
  - Front-stage vs. back-stage self (dramaturgical approach) (SOC)
- Verbal and nonverbal communication
- Animal signals and communication (PSY, BIO)

Social Behavior (PSY)

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

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

Psychological, Social, and Biological Foundations of Behavior

Foundational Concept 9

Cultural and social differences influence well-being.

Social structure and demographic factors influence people's health and well-being. Knowledge about basic sociological theories, social institutions, culture, and demographic characteristics of societies is important to understand how these factors shape people's lives and their daily interactions.

Foundational Concept 9 focuses on social 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.

With these building blocks, medical students will be able to learn about the ways patients' social and demographic backgrounds influence their perception of health and disease, the health care team, and therapeutic interventions.

9A: Understanding social structure

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

The content in this category provides a foundation for understanding social structure and the various forms of interactions within and among societies. It includes theoretical approaches to studying society and social groups, specific social institutions relevant to student preparation for medical school, and the construct of culture.

Theoretical Approaches (SOC)

- Microsociology vs. macrosociology
- Functionalism
- Conflict theory
- Symbolic interactionism
- Social constructionism
- Exchange-rational choice
- Feminist theory

Social Institutions (SOC)

- Education
  - Hidden curriculum
  - Teacher expectancy
  - Educational segregation and stratification
- Family (PSY, SOC)
  - Forms of kinship (SOC)
  - Diversity in family forms
  - Marriage and divorce
  - Violence in the family (e.g., child abuse, elder abuse, spousal abuse) (SOC)

	▪ Religion ○ Religiosity ○ Types of religious organizations (e.g., churches, sects, cults) ○ Religion and social change (e.g., modernization, secularization, fundamentalism) ▪ Government and economy ○ Power and authority ○ Comparative economic and political systems ○ Division of labor ▪ Health and medicine ○ Medicalization ○ The sick role ○ Delivery of health care ○ Illness experience ○ Social epidemiology **Culture (PSY, SOC)** ▪ Elements of culture (e.g., beliefs, language, rituals, symbols, values) ▪ Material vs. symbolic culture (SOC) ▪ Culture lag (SOC) ▪ Culture shock (SOC) ▪ Assimilation (SOC) ▪ Multiculturalism (SOC) ▪ Subcultures and countercultures (SOC) ▪ Mass media and popular culture (SOC) ▪ Evolution and human culture (PSY, BIO) ▪ Transmission and diffusion (SOC)
9B: Demographic characteristics and processes To understand the structure of a society, it is important to understand the demographic characteristics and processes that define it. Knowledge of the demographic structure of societies and an understanding of how societies change help us comprehend the distinct processes and mechanisms through which social interaction occurs.	**Demographic Structure of Society (PSY, SOC)** ▪ Age ○ Aging and the life course ○ Age cohorts (SOC) ○ Social significance of aging ▪ Gender ○ Sex vs. gender ○ The social construction of gender (SOC) ○ Gender segregation (SOC)

The content in this category covers the important demographic variables at the core of understanding societies and includes concepts related to demographic shifts and social change.	▪ Race and ethnicity (SOC) ○ The social construction of race ○ Racialization ○ Racial formation ▪ Immigration status (SOC) ○ Patterns of immigration ○ Intersections with race and ethnicity ▪ Sexual orientation **Demographic Shifts and Social Change (SOC)** ▪ Theories of demographic change (e.g., Malthusian theory and demographic transition) ▪ Population growth and decline (e.g., population projections, population pyramids) ▪ Fertility, migration, and mortality ○ Fertility and mortality rates (e.g., total, crude, age-specific) ○ Patterns in fertility and mortality ○ Push and pull factors in migration ▪ Social movements ○ Relative deprivation ○ Organization of social movements ○ Movement strategies and tactics ▪ Globalization ○ Factors contributing to globalization (e.g., communication technology, economic interdependence) ○ Perspectives on globalization ○ Social changes in globalization (e.g., civil unrest, terrorism) ▪ Urbanization ○ Industrialization and urban growth ○ Suburbanization and urban decline ○ Gentrification and urban renewal

Psychological, Social, and Biological Foundations of Behavior

Foundational Concept 10

Social stratification and access to resources influence well-being.

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

Foundational Concept 10 focuses on the aspects of social inequality that influence how we interact with one another, as well as how we approach our health and the health care system.

Content Category

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

With these building blocks, medical students will be able to learn about the ways social and economic factors can affect access to care and the probability of maintaining health and recovering from disease.

10A: Social inequality

Barriers to access to institutional resources exist for the segment of the population that is disenfranchised or lacks power within a given society. Barriers to access might include language, geographic location, socioeconomic status, immigration status, and racial/ethnic identity. Institutionalized racism and discrimination are also factors that prevent some groups from obtaining equal access to resources. An understanding of the barriers to access to institutional resources, informed by perspectives such as social justice, is essential to address health and health care disparities.

The content in this category covers spatial inequality, the structure and patterns of social class, and health disparities in relation to class, race/ethnicity, and gender.

Spatial Inequality (SOC)

- Residential segregation
- Neighborhood safety and violence
- Environmental justice (location and exposure to health risks)

Social Class (SOC)

- Aspects of social stratification
  - Social class and socioeconomic status
  - Class consciousness and false consciousness
  - Cultural capital and social capital
  - Social reproduction
  - Power, privilege, and prestige
  - Intersectionality (e.g., race, gender, age)
  - Socioeconomic gradient in health
  - Global inequalities
- Patterns of social mobility
  - Intergenerational and intragenerational mobility
  - Vertical and horizontal mobility
  - Meritocracy

	▪ Poverty ○ Relative and absolute poverty ○ Social exclusion (segregation and isolation) **Health Disparities (SOC)** (e.g., class, gender, and race inequalities in health) **Health Care Disparities (SOC)** (e.g., class, gender, and race inequalities in health care)

Critical Analysis and Reasoning Skills

What Will the Critical Analysis and Reasoning Skills Section Test?

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

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

This section is designed to:

- Test your comprehension, analysis, and reasoning skills by asking you to critically analyze information provided in passages.
- Include content from ethics, philosophy, studies of diverse cultures, population health, and a wide range of social sciences and humanities disciplines.
- Provide all the information you need to answer questions in the passages and questions themselves.

Test Section	Number of Questions	Time
Critical Analysis and Reasoning Skills	53 (note that questions are all passage-based)	90 minutes

Critical Analysis and Reasoning Skills Distribution of Questions by Critical Analysis and Reasoning Skill and Passage Content in the Humanities and Social Sciences

You may wonder how many questions you'll get testing a particular critical analysis and reasoning skill or how many humanities or social science passages you'll see on the test. The questions you see are likely to be distributed in the ways described below. (These percentages have been approximated to the nearest 5% and will vary from one test to another for a variety of reasons, including, but are not limited to, controlling for question difficulty, using groups of questions that depend on a single passage, and using unscored field-test questions on each test form.)

Critical Analysis and Reasoning Skill:

- Foundations of Comprehension, 30%
- Reasoning Within the Text, 30%
- Reasoning Beyond the Text, 40%

Passage Content:

- Humanities, 50%
- Social Sciences, 50%

What Is the Content of the Passages in the Critical Analysis and Reasoning Skills Section?

Passages in the Critical Analysis and Reasoning Skills section are excerpted from the kinds of books, journals, and magazines that college students are likely to read. Passages from the social sciences and humanities disciplines might present interpretations, implications, or applications of historical accounts, theories, observations, or trends of human society as a whole, specific population groups, or specific countries.

Of these two types of passages (social sciences and humanities), social sciences passages tend to be more factual and scientific in tone. For example, a social sciences passage might discuss how basic psychological and sociological assumptions help scholars reconstruct patterns of prehistoric civilizations from ancient artifacts. Humanities passages often focus on the relationships between ideas and 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. Humanities passages might describe the ways art reflects historical or social change or how the philosophy of ethics has adapted to prevailing technological changes.

Critical Analysis and Reasoning Skills passages come from a variety of humanities and social sciences disciplines.

Humanities

Passages in the humanities are drawn from a variety of disciplines, including (but not limited to):

- Architecture
- Art
- Dance
- Ethics
- Literature
- Music
- Philosophy
- Popular Culture
- Religion
- Theater
- Studies of Diverse Cultures[†]

Social Sciences

Social sciences passages are also drawn from a variety of disciplines, including (but not limited to):

- Anthropology
- Archaeology
- Economics
- Education
- Geography
- History
- Linguistics
- Political Science
- Population Health
- Psychology
- Sociology
- Studies of Diverse Cultures

[†] Depending on the focus of the text, a Studies of Diverse Cultures passage could be classified as belonging to either the Humanities or Social Sciences.

What Kinds of Analysis Skills Does the Critical Analysis and Reasoning Skills Section Require?

The Critical Analysis and Reasoning Skills section assesses three broad critical analysis and reasoning skills. Questions in this section will ask you to determine the overall meaning of the text, to summarize, evaluate, and critique the "big picture," and to synthesize, adapt, and reinterpret concepts you processed and analyzed. The questions that follow Critical Analysis and Reasoning Skills passages lead you through this complex mental exercise of finding meaning within each text and then reasoning beyond the text to expand the initial meaning. The analysis and reasoning skills you will be tested on mirror those that mature readers use to make sense of complex materials. The skills assessed in the Critical Analysis and Reasoning Skills section are listed below, and each skill is explained in the following sections.

Critical Analysis and Reasoning Skills

Foundations of Comprehension

- Understanding the basic components of the text
- Inferring meaning or intent from immediate sentence context

Reasoning Within the Text

- Integrating distant components of the text to infer an author's message, intent, purpose, belief, position, bias, assumptions
- Recognizing and evaluating arguments and their structural elements (claims, evidence, support, relations)

Reasoning Beyond the Text

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

Foundations of Comprehension

The topics of some passages in the Critical Analysis and Reasoning Skills section will be familiar; some will not. Explanations, illustrative examples, and definitions of significant specialized terms in these passages will help you develop the strong basic foundation needed for answering all the questions you encounter in this section of the MCAT exam. Questions that test Foundations of Comprehension rely on many of the same activities required for Reading Within the Text questions. One key difference is in the scope of the information needed to answer the question. The Foundations of Comprehension questions mainly focus on inferring meaning or intent from an immediate sentence context.

Additionally, some questions may ask you about the overall meaning of information in the passages or the author's central themes or ideas; others may ask you to select the definitions of specific words or phrases as they are used in context. These kinds of questions help you build the foundation that will allow you to think in new ways about concepts or facts presented in the passages. Paragraph numbers may be included in questions to help you locate relevant portions of the text.

Two sets of skills are the basis of the Foundations of Comprehension questions on the Critical Analysis and Reasoning Skills section.

Understanding the Basic Components of the Text

The most fundamental questions on the Critical Analysis and Reasoning Skills section ask about the basic components of the passages. Comprehension questions at this level may ask you to provide a general overview of the passage or to focus on specific portions of the text. You may be asked to recognize the literal meaning of a particular word or phrase. You may be asked to identify the author's thesis, the main point or theme of the passage, or specific examples. In responding to these questions, you need to be able to recognize the purpose of particular sentences and rhetorical labels such as "for example," "therefore," or "consequently."

Inferring Meaning or Intent From Immediate Sentence Context

Questions may also require you to infer meanings that can't be determined from a literal reading of the text, such as meanings the author has implied but did not state directly. Comprehension questions at this level may ask you to interpret the meaning of words or expressions, or the author's intent, using the immediate sentence context. These questions may ask you to interpret rhetorical devices or word choice. Or, you may have to consider how the author has structured the text — for example, through cause-and-effect relationships for discussions in the behavioral sciences, chronologically for historical discussions, or point-and-counterpoint for political science pieces. Identifying the basic structure should help you understand the passage and determine its general purpose.

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

Some questions at this level may ask about information not specifically stated in the passage, and you must make assumptions based on what the author merely hints at through his or her use of connotative language or figures of speech.

The beginning and ending of passages are two specific sections where the author often provides important information about the general theme, message, or purpose for the work. Does the author state their main point in an introductory or closing sentence? Does the passage end with a definitive solution, a partial resolution, or a call for additional research? Does it end with a dramatic rhetorical statement or a joke that leaves unanswered questions? Again, considering these specific sections can help inform your basic understanding of the passage.

Reasoning Within the Text

Questions that test Reasoning Within the Text rely on many of the same activities required for Foundations of Comprehension questions. One key difference is in the scope of the information needed to answer the question. The Foundations of Comprehension questions mainly focus on inferring

meaning or intent from an immediate sentence context. Questions that test Reasoning Within the Text differ from those assessing Foundations of Comprehension in that they ask you to integrate distant passage components into a more generalized and complex interpretation of passage meaning.

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

Two sets of skills are the basis of the Reasoning Within the Text questions on the Critical Analysis and Reasoning Skills section.

Integrating Distant Components of the Text

Many questions that test Reasoning Within the Text skills require you to integrate distant components of the text to infer meaning or intent. You may be asked to determine an author's message, purpose, position, or point of view. This may also extend to inferring their beliefs, noticing their assumptions, and detecting bias. When it is not directly stated in any single sentence, you may be asked to infer what the author's main thesis might be. You may be asked to consider whether each section of text contributes to a sustained train of thought, as opposed to presenting an isolated detail or digressing from the central theme. You may be asked about paradoxes, contradictions, or inconsistencies that can be detected across different parts of the passage. You will also need to be able to recognize when an author presents different points of view within the passage.

To infer the author's beliefs, attitudes, or bias, look for clues in the tone of the passage, in the author's use of language or imagery, and in the author's choice of sources. To determine the author's position, look for their expressed point of view. Carefully consider the extent to which the author uses summaries or paraphrases to introduce others' points of view. It's very important to attend to perspective: Does the author present their own perspective, or do they use verbatim quotations or restatements from the perspective of other sources? You may be asked to identify points of view, other than the author's, presented indirectly through the author's summaries or paraphrases.

Recognizing and Evaluating Arguments

Questions assessing Reasoning Within the Text will also require you to understand how the different parts of the passage fit together to support the author's central thesis. Some questions will direct your attention to an argument, claim, or evidence presented in the passage and then ask you to evaluate it according to specific criteria. The criteria could be the logic and plausibility of the passage text, the soundness of its arguments, the reasonableness of its conclusions, the appropriateness of its generalizations, or the credibility of the sources the author cites. The questions require you to dig beneath the passage's surface as you examine the presence or absence of evidence, the relevance of information, and faulty notions of causality and to determine the significance of and relationships among different parts of a passage. Some questions may require that you analyze the author's language,

stance, and purpose. For example, plausible-sounding transitional phrases may in fact be tricky. If read quickly, the words appear to make a legitimate connection between parts of a passage; however, when subjected to scrutiny, the links they appear to have established may fall apart.

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

Reasoning Beyond the Text

The final category, Reasoning Beyond the Text, requires you to use one of two analysis or reasoning skills, which in a way can be thought of as two sides of a single coin. Questions assessing the first set of skills ask you to *apply or extrapolate* information or ideas presented in the passage to a new or novel situation — for example, extending information the author presents beyond the actual context of the passage.

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

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

Applying or Extrapolating Ideas From the Passage to New Contexts

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

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

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

Application questions sometimes require selecting a response option that is most *analogous* to some relationship in the passage. Here the parameters are broad. *Likeness* is measured not by inherent similarity but by analogy. Questions dealing with analogies test the ability to identify a fundamental common feature that seemingly different things or processes share. This may sometimes require translating a figurative comparison into equivalent sets of literal terms. However, the task always requires looking beneath surface imagery to discern underlying relationships or paradigms.

Assessing the Impact of Incorporating New Factors, Information, or Conditions on Ideas From the Passage

The essential difference between application and incorporation skills is that the two-part purpose of incorporation questions is to introduce a specific piece of information for you to consider and ask you to assess how ideas in the passage might be affected by its introduction. The premise of these questions is that ideas and information in the passages are potentially malleable, not a fixed framework, as in application questions.

In some incorporation questions, you must find the best answer to a "what if" question by reinterpreting and reassessing passage content with the additional fact or idea introduced by the question. Does the new information support or contradict the inherent logic of the passage? Could the new information coexist with what is already in the passage, or would it negate an aspect of the

author's argument? If the latter is the case, the question could ask what modifications or alterations might need to be made to the passage content to accommodate the new element introduced by the question. Remember, the passage should be considered malleable.

Other forms of incorporation questions may ask you to think about a possible logical relationship that might exist between the passage content and the facts or assertions included in the answer options. The task is to select the one option that, if added to the passage content, would result in the *least* amount of change. The correct response option will present the situation or argument that is most similar to what is outlined in the passage. In other words, you must determine which new fact or assertion would least alter the central thesis the passage has developed.

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