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

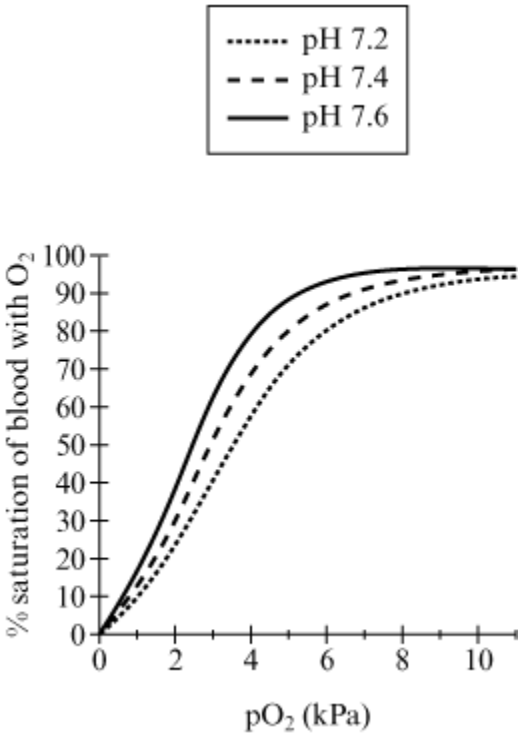
Which correlation supports the bystander effect?

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.