Biology/Life Science Subject Matter Requirements

Part I: Content Domains for Subject Matter Understanding and Skill in Biology/Life Science

Domain 1. Cell Biology and Physiology

Candidates demonstrate an understanding of the foundations of the cell biology and physiology contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of cell biology and physiology and their underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate an understanding of the fundamental life processes of plants and animals that depend on a variety of chemical reactions that occur in specialized areas of an organism's cells. They recognize the coordination of organ systems and the relationship of structure to function. They use this understanding to apply the concepts of homeostasis and its mechanisms to the regulation of human body systems.

1.1 Prokaryotic and Eukaryotic Cells

a. Compare prokaryotic cells, eukaryotic cells, and viruses in terms of complexity, general structure, differentiation, and their requirements for growth and replication

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 1c, 1d)

1.2 Cellular Reproduction

a. Describe the stages of the cell cycle
b. Diagram and describe the stages of the mitotic process

(Science Content Standards for California Public Schools, Grades 7: 1e)

1.3 Plant and Animal Cell Anatomy and Physiology

a. Diagram the structure of the cell membrane and relate the structure to its function
b. Explain methods of transport across the membrane (e.g., diffusion, active transport, endocytosis and exocytosis)
c. Explain the role of semipermeable membranes in cellular communication
d. Explain the role of the endoplasmic reticulum and Golgi apparatus in the secretion of proteins
e. Explain the role of chloroplasts in obtaining and storing usable energy
f. Explain the role of mitochondria in cellular respiration
g. Explain the role of enzymes in chemical reactions and describe an experiment to test the catalytic role of enzymes and factors that affect enzyme activity (e.g., levels of protein organization, temperature, ionic conditions, concentration of enzyme and substrate, pH)
h. Explain anabolic and catabolic pathways involved in the metabolism of macromolecules (e.g., polysaccharides, nucleic acids, proteins, lipids)

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 1a-b, 1d-j)

1.4 Integration and Control of Human Organ Systems

a. Relate the complementary activity of major body systems (e.g., circulatory, digestive, respiratory, excretory) to provide cells with oxygen and nutrients and remove waste products
b. Explain and analyze the role of the nervous system in mediating communication between different parts of the body and the body's interactions with the environment
c. Explain the homeostatic role of the major organs (e.g., kidneys, heart, brain)
d. Explain the function of feedback loops in the nervous and endocrine systems to regulate conditions in the body and predict the effects of disturbances on these systems
e. Explain the role of hormones (e.g., digestive, reproductive, osmoregulatory) in providing internal feedback mechanisms for homeostasis at the cellular level and in whole organisms
f. Describe the role of the musculo-skeletal system in providing structure, support, and locomotion to the human organism

(Science Content Standards for California Public Schools, Grade 7: 5a-b; Grades 9-12, Biology/Life Sciences: 9a-i)

1.5 Physiology of the Immune System

a. Explain the humoral response to infection
b. Compare cell mediated and humoral responses to infection
c. Explain how vaccination works and distinguish among variables affecting success rate
d. Predict the consequences of a compromised immune system [e.g., AIDS (Acquired Immune Deficiency Syndrome)]

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 10b-f)

Domain 2. Genetics

Candidates demonstrate an understanding of the foundations of the genetics contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of genetics and its underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate understanding of the structure and function of genetic material. They understand the genetic coding of DNA (deoxyribonucleic acid) and how this coding specifies the sequence of amino acids in proteins characteristic of the organism. Candidates know that a multicellular organism develops from a single zygote, and its phenotype depends on its genotype, which is established at fertilization. They understand the roles of mutation and sexual reproduction in genetic variation within populations. They know how new biotechnology methods incorporate exogenous DNA into cells to alter their genetic composition, and the resulting ethical implications of using such methods. Candidates also understand the relationship of genetics to evolution and how the frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time.

2.1 Chromosome Structure and Function

a. Relate the structure and function of DNA, RNA (ribonucleic acid), and proteins to the concept of variation in organisms
b. Describe chromosome structure as a sequence of genes each with a specific locus

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 1d, 3d, 4a-c, 4e, 5a-b)

2.2 Patterns of Inheritance

a. Explain the necessity of both meiosis and fertilization in promoting variation
b. Describe the role of chromosomes in determining phenotypes (e.g., sex determination, chromosomal aberrations)
c. Predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (e.g., autosomal or X-linked, dominant or recessive, co-dominance)
d. Explain the genetic and cellular bases for Mendel's laws of dominance, segregation and independent assortment

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 2a-g, 3b-c, 8a)

2.3 Gene Expression

a. Explain how random chromosome segregation explains the probability that a particular allele will be in a gamete
b. Recognize that specialization of cells in multicellular organisms is usually due to different patterns of gene expression rather than to differences among the genes themselves
c. Describe how alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool
d. Distinguish when and why mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 3a, 4c-d, 7b-c)

2.4 Biotechnology

a. Recognize how genetic engineering (biotechnology) produces biomedical and agricultural products
b. Describe the construction of recombinant DNA molecules by basic DNA technology including restriction digestion by endonucleases, gel electrophoresis, ligation, and transformation

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 5c-e)

2.5 Bioethics

a. Discuss issues of bioethics including genetic engineering, cloning, the human genome project, gene therapy, and medical implications

(Science Content Standards for California Public Schools, Grades 9-12, Investigation and Experimentation:1m)

Domain 3. Evolution

Candidates demonstrate an understanding of the foundations of the evolution contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of evolution and its underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates explain that evolution is the result of genetic changes that occur in constantly changing environments. They know that the frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time. Based on available evidence, they relate evolutionary theory to the history of life on Earth.

3.1 Natural Selection

a. Explain why natural selection acts on the phenotype rather than the genotype of an organism
b. Predict the survival potential of various groups of organisms based on the amount of diversity in their gene pools

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 7a-d)

3.2 Evolutionary Patterns

a. Analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction
b. Analyze the effects of evolutionary patterns on the diversity of organisms (e.g., genetic drift, convergent evolution, punctuated equilibrium, patterns of selection)
c. Explain the conditions for Hardy-Weinberg equilibrium and why they are unlikely to appear in nature, and solve equations to predict the frequency of genotypes in a population

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 7e-f, 8b-c, 8e)

3.3 Mechanisms for Speciation

a. Distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change
b. Describe a scenario that demonstrates the effects of reproductive or geographic isolation on speciation

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 6g, 8d)

3.4 History and Origin of Life

a. Explain the theoretical origins of life on Earth
b. Construct a branching diagram (cladogram) from a variety of data sources illustrating the phylogeny between organisms of currently identified taxonomic groups

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 8f-g)

Domain 4. Ecology

Candidates demonstrate an understanding of the foundations of the ecology contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of ecology and its underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate understanding that stability in an ecosystem is a balance among competing effects. They understand the interrelationships within ecosystems, the flow of matter and energy through ecosystems, and how humans impact the environment.

4.1 Biodiversity

a. Define biodiversity and describe the effects on biodiversity of alteration of habitat

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 6a-b)

4.2 Energy Flow and Nutrient Cycles

a. Evaluate the importance of stability of producers, consumers, and decomposers

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 6e-f)

4.3 Interrelationships and Change in Ecosystems

a. Describe various species interactions (e.g., predator/prey, parasitism, mutualism, commensalism, competition)
b. Analyze the fluctuations in population size in an ecosystem due to the relative rates of birth, immigration, emigration, and death
c. Analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, and changes in population size

(Science Content Standards for California Public Schools, Grades 9-12, Biology/Life Sciences: 6b-c)

Part II: Subject Matter Skills and Abilities Applicable to the Content Domains in Science

Domain 1. Investigation and Experimentation

Candidates for Single Subject Teaching Credentials in Science formulate and conduct scientific investigations. They select appropriate scientific tools, make relevant measurements of changes in natural phenomena, and present unbiased findings in logical and meaningful formats using charts, maps, tables, models, graphs, and labeled diagrams. Candidates apply mathematics to scientific investigations and experimentation(s) for the purpose of quantifying results and drawing conclusions. Candidates interpret experimental results and determine whether further information is necessary to

formulate accurate conclusions. They communicate results through various methods, and use technology where appropriate.

1.1 Question Formulation

a. Formulate and evaluate a viable hypothesis
b. Recognize the value and role of observation prior to question formulation
c. Recognize the iterative nature of questioning
d. Given an experimental design, identify possible hypotheses that it may test

(Science Content Standards for California Public Schools, Grade 6: 7a)

1.2 Planning a Scientific Investigation (including Experimental Design)

a. Given a hypothesis, formulate an investigation or experimental design to test that hypothesis
b. Evaluate an experimental design for its suitability to test a given hypothesis
c. Distinguish between variable and controlled parameters

(Science Content Standards for California Public Schools, Grade 5: 6c-d; Grade 8: 9a, 9c)

1.3 Observation and Data Collection

a. Identify changes in natural phenomena over time without manipulating the phenomena (e.g., a tree limb, a grove of trees, a stream, a hill slope)
b. Analyze the locations, sequences, and time intervals that are characteristic of natural phenomena (e.g., locations of planets over time, succession of species in an ecosystem)
c. Select and use appropriate tools and technology (e.g., computer-linked probes, spreadsheets, graphing calculators) to perform tests, collect data, analyze relationships, and display data
d. Evaluate the precision, accuracy, and reproducibility of data
e. Identify and analyze possible reasons for inconsistent results, such as sources of error or uncontrolled conditions
f. Identify and communicate sources of unavoidable experimental error
g. Recognize the issues of statistical variability and explain the need for controlled tests
h. Know and evaluate the safety issues when designing an experiment and implement appropriate solutions to safety problems
i. Appropriately employ a variety of print and electronic resources (e.g., the World Wide Web) to collect information and evidence as part of a research project
j. Assess the accuracy validity and reliability of information gathered from a variety of sources

(Science Content Standards for California Public Schools, Grade 3: 5a; Grade 6: 7a-b, 7g-h; Grade 7: 7a-b; Grade 8: 9b; Grades 9-12, Investigation and Experimentation: 1a-c, 1i-j, 1m)

1.4 Data Analysis/Graphing

a. Construct appropriate graphs from data and develop qualitative and quantitative statements about relationships between variables
b. Recognize the slope of the linear graph as the constant in the relationship y=kx and apply this principle in interpreting graphs constructed from data

c. Apply simple mathematical relationships to determine a missing quantity in an algebraic expression, given the two remaining terms (e.g., speed = distance/time, density = mass/volume, force = pressure x area, volume = area x height)
d. Determine whether a relationship on a given graph is linear or non-linear and determine the appropriateness of extrapolating the data
e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions

(Science Content Standards for California Public Schools, Grade 6: 7c; Grade 8: 9d-g; Grades 9-12, Investigation and Experimentation: 1e)

1.5 Drawing Conclusions and Communicating Explanations

a. Draw appropriate and logical conclusions from data
b. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence
c. Communicate the steps and results of an investigation in written reports and oral presentations
d. Recognize whether evidence is consistent with a proposed explanation
e. Construct appropriate visual representations of scientific phenomenon and processes (e.g., motion of Earth's plates, cell structure)
f. Read topographic and geologic maps for evidence provided on the maps and construct and interpret a simple scale map

(Science Content Standards for California Public Schools, Grade 5: 6g; Grade 6: 7e-f; Grade 7: 7c-e; Grade 8: 9a; Grades 9-12, Investigation and Experimentation: 1d, 1h)

Domain 2. Nature of Science

Candidates recognize that science is an active endeavor in which acquisition of knowledge is based upon the collection and examination of data. Candidates understand that scientists have a responsibility to report fully and openly the methods and results of their observations and experiments, even if those results disagree with their favored hypotheses or are controversial in public opinion. They understand that to hide data, arbitrarily eliminate data, or conceal how an experiment was conducted is to invite errors, make those errors difficult to discover, and risk harm to colleagues and communities. They understand that scientists carefully consider questions and challenges raised by fellow scientists about the assumptions, procedures, and accuracy of their experiments. They understand that a fundamental aspect of scientific inquiry is that it is dynamic and self-correcting by design. Conclusions, hypotheses, and theories are tested in every experiment and revised or rejected when they no longer correctly or accurately predict experimental results. Candidates understand that scientists must consider the safety, ethical concerns, risks, and costs and benefits of experiments to society.

2.1 Scientific Inquiry

a. Distinguish among the terms hypothesis, theory, and prediction as used in scientific investigations
b. Evaluate the usefulness, limitations, and interdisciplinary and cumulative nature of scientific evidence as it relates to the development of models and theories as representations of reality

c. Recognize that when observations do not agree with an accepted scientific theory, either the observations are mistaken or fraudulent, or the accepted theory is erroneous or incorrect
d. Understand that reproducibility of data is critical to the scientific endeavor
e. Recognize that science is a self-correcting process that eventually identifies misconceptions and experimental biases
h. Recognize that an inquiring mind is at the heart of the scientific method and that doing science involves thinking critically about the evidence presented, the usefulness of models, and the limitations of theories
i. Recognize that theories are judged by how well they explain observations and predict results and that when they represent new ideas that are counter to mainstream ideas they often encounter vigorous criticism
j. Recognize that when observations, data, or experimental results do not agree, the unexpected results are not necessarily mistakes; to discard the unusual in order to reach the expected is to guarantee that nothing but what is expected will ever be seen
k. Know why curiosity, honesty, openness, and skepticism are so highly regarded in science and how they are incorporated into the way science is carried out

(Science Content Standards for California Public Schools, Grade 6: 7e; Grades 9-12, Investigation and Experimentation: 1f-g, 1n)

2.2 Scientific Ethics

a. Understand that honesty is at the core of scientific ethics; first and foremost is the honest and accurate reporting of procedures used and data collected
b. Know that all scientists are obligated to evaluate the safety of an investigation and ensure the safety of those performing the experiment
c. Know the procedures for respectful treatment of all living organisms in experimentation and other investigations

2.3 Historical Perspectives

a. Discuss the cumulative nature of scientific evidence as it relates to the development of models and theories
b. Recognize that as knowledge in science evolves, when observations do not support an accepted scientific theory, the observations are reconsidered to determine if they are mistaken or fraudulent, or if the accepted theory is erroneous or incomplete (e.g., an erroneous theory is the Piltdown Man fossil; an incomplete theory is Newton's laws of gravity)
c. Recognize and provide specific examples that scientific advances sometimes result in profound paradigm shifts in scientific theories
d. Discuss the need for clear and understandable communication of scientific endeavors so that they may be reproduced and why reproduction of these endeavors is important

(Science Content Standards for California Public Schools, Grade 6: 7d; Grade 7: 7c, 7e; Grades 9-12, Investigation and Experimentation: 1k, 1n)

Domain 3. Science and Society

Candidates understand that science relies on basic human qualities such as reasoning, insight, curiosity, skill, and creativity – as well as on scientific habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. Candidates recognize their responsibility to increase scientific literacy so that the general population can understand current issues and appreciate their personal roles and responsibilities. Candidates know about possible hazards and take precautions that are the basis for creating a safe learning environment that benefits all students. They are familiar with established rules and guidelines that intend to ensure the safety of students and to protect the subjects and environments studied. Candidates understand that technology is the application of proven scientific knowledge for practical purposes serving human needs; however, science and technology are interrelated—one often propels the other.

3.1 Science Literacy

a. Recognize that science attempts to make sense of how the natural and the designed world function
b. Demonstrate the ability to apply critical and independent thinking to weigh alternative explanations of events
c. Apply evidence, numbers, patterns, and logical arguments to solve problems
d. Understand that, although much has been learned about the objects, events and phenomena in nature, there are many unanswered questions, i.e., science is a work in progress
e. Know that the ability of science and technology to resolve societal problems depends on the scientific literacy of a society

3.2 Diversity

a. Identify examples of women and men of various social and ethnic backgrounds with diverse interests, talents, qualities and motivations who are, or who have been, engaged in activities of science and related fields

3.3 Science, Technology, and Society

a. Identify and evaluate the impact of scientific advances on society
b. Recognize that scientific advances may challenge individuals to reevaluate their personal beliefs

(Science Content Standards for California Public Schools, Grades 9-12, Investigation and Experimentation: 1m, 1n)

3.4 Safety

a. Choose appropriate safety equipment for a given activity (e.g., goggles, apron, vented hood)
b. Discuss the safe use, storage, and disposal of commonly used chemicals and biological specimens
c. Assess the safety conditions needed to maintain a science laboratory (e.g., eye wash, shower, fire extinguisher)
d. Read and decode MSDS/OSHA (Material Safety Data Sheet/Occupational Safety and Health Administration) labels on laboratory supplies and equipment
e. Discuss key issues in the disposal of hazardous materials in either the laboratory or the local community
f. Be familiar with standard safety procedures such as those outlined in the Science Safety Handbook for California Schools (1999)