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The Science of Energy

How energy is stored, transformed, transferred, and conserved across physical systems and how these processes govern motion, matter, and technology.

Grades 9-12

SC.912.EN.1 Explain the forms, conservation, transfer, efficiency, and sources of energy to describe how energy is stored, moves between systems, and powers natural and human made processes.

SC.912.EN.1.1 Distinguish among the forms of energy.

Benchmark Clarifications:

Clarification 1: Instruction includes kinetic, gravitational potential, elastic potential, thermal, chemical, electrical, sound, nuclear and electromagnetic energy, including visible light.

Clarification 2: Instruction includes using models to classify and represent forms of energy. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes examining historical developments that contributed to scientific understanding of energy forms. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.1.2 Explain the Law of Conservation of Energy.

Benchmark Clarifications:

Clarification 1: Instruction includes recognizing that energy cannot be created or destroyed but can change form.

Clarification 2: Instruction includes that in closed systems total energy is conserved.

Clarification 3: Instruction includes using models to represent energy conservation within closed systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes using evidence to support energy conservation in real-world systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of the Law of Conservation of Energy. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.1.3 Identify the mechanisms of thermal energy transfer.

Benchmark Clarifications:

Clarification 1: Instruction includes conduction, convection, and radiation.

Clarification 2: Instruction includes using models to represent energy transfer mechanisms. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes analyzing experimental evidence of energy transfer. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.1.4 Explain the principles of efficiency.

Benchmark Clarifications:

Clarification 1: Instruction includes qualitative efficiency as useful output over input.

Clarification 2: Instruction includes reading and interpreting energy bar charts and energy flow diagrams to identify relationships among energy input, useful output, and losses. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes using models such as energy flow diagrams to represent efficiency. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EN.1.5 Recall renewable sources of energy.

Benchmark Clarifications:

Clarification 1: Instruction includes renewable sources of energy: solar, wind, hydro, geothermal, and biomass.

Clarification 2: Instruction includes availability, intermittency, and environmental impacts.

Clarification 3: Instruction includes interpreting and comparing data related to availability, intermittency, and environmental impacts. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing data to compare energy sources and evaluate trade-offs. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.1.6 Recall nonrenewable sources of energy.

Benchmark Clarifications:

Clarification 1: Instruction includes nonrenewable sources of energy: fossil fuels and nuclear fission.

Clarification 2: Instruction includes availability, resource limitations, and environmental impacts.

Clarification 3: Instruction includes interpreting and comparing data related to availability, intermittency, and environmental impacts. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing data to compare energy sources and evaluate trade-offs. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EN.2 Explain how work, kinetic and potential energy, power, and the conservation of mechanical energy describe and predict the motion of systems and apply mathematical relationships to calculate these quantities and account for changes due to non-conservative forces.

SC.912.EN.2.1 Calculate work with appropriate units.

Benchmark Clarifications:

Clarification 1: Instruction includes $W=Fd\cos(\theta)$, where W is work, F is the applied force, d is the displacement, and θ is the angle between the force and the displacement.

Clarification 2: Instruction includes the International System of Units (SI) unit for work: joule (J).

Clarification 3: Instruction includes applying algebraic reasoning and dimensional analysis to solve equations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes describing and predicting the motion of systems by analyzing and explaining measured data and calculations. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.2.2 Calculate kinetic energy with appropriate units.

Benchmark Clarifications:

Clarification 1: Instruction includes $KE=1/2\ mv^2$, where KE is in joules (J), m in kilograms (kg), and v in meters per second (m/s).

Clarification 2: Instruction includes the International System of Units (SI) unit of energy: joule (J).

Clarification 3: Instruction includes applying algebraic reasoning and dimensional analysis to solve equations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing measured data to support calculations. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EN.2.3 Calculate power with appropriate units.

Benchmark Clarifications:

Clarification 1: Instruction includes P = W/t, where: P is the power, W is the work done, and t is the time taken to do that work.

Clarification 2: Instruction includes the International System of Units (SI) unit for power: watt (W).

Clarification 3: Instruction includes applying algebraic reasoning and dimensional analysis to solve equations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing measured data to support calculations. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.2.4 Explain the relationship among work, energy, and power using real-world applications.

Benchmark Clarifications:

Clarification 1: Instruction includes using models and real-world data to explain energy concepts. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.2.5 Apply the work-energy theorem.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship $W_{net}=\Delta K$, where net work equals the change in kinetic energy.

Clarification 2: Instruction includes calculating net work from force-displacement information and interpreting signs for positive or negative work.

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Clarification 3: Instruction includes using mathematical relationships to represent connections between work and energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using graphical models to represent relationships between work and energy. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.2.6 Apply conservation of mechanical energy and account for non-conservative work.

Benchmark Clarifications:

Clarification 1: Instruction includes K_i+U_i=K_f+U_f when non-conservative work is negligible.

Clarification 2: Instruction includes the generalized energy accounting K_i+U_i+W_"nc" =K_f+U_f, where W_"nc" , as friction or air resistance, converts mechanical energy to thermal energy.

Clarification 3: Instruction includes using mathematical relationships to represent connections between work and energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using graphical models to represent relationships between work and energy. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.2.7 Calculate gravitational potential energies and describe the solution in real-world contexts.

Benchmark Clarifications:

Clarification 1: Instruction includes U_g=mgh, where near Earth is constant g and requires selecting a reference level for h.

Clarification 2: Instruction includes using energy bar charts and graphs to analyze scenarios such as ramps and pendulums and relating changes in U_g to changes in kinetic energy.

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Clarification 3: Instruction includes applying algebraic relationships and interpreting graphical representations of energy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using graphs and models to represent energy changes in systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.2.8 Calculate elastic potential energies and describe the solution in real-world contexts.

Benchmark Clarifications:

Clarification 1: Instruction includes $U_s=1/2\ kx^2$, Hooke's Law $F=kx$, and identifying spring constant k and displacement x from equilibrium.

Clarification 2: Instruction includes using energy bar charts and graphs for mass–spring systems and spring-loaded devices and relating changes in U_s to changes in kinetic energy.

Clarification 3: Instruction includes applying algebraic relationships and interpreting graphical representations of energy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using graphs and models to represent energy changes in systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3 Explain how temperature, heat transfer, and enthalpy changes describe and predict thermal energy flow in physical and chemical systems; apply particle models, heat transfer mechanisms, calorimetry, and energy diagrams to distinguish heat from temperature; quantify energy changes in temperature and phase processes; and interpret endothermic and exothermic transformations.

SC.912.EN.3.1 Distinguish heat from temperature.

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Benchmark Clarifications:

Clarification 1: Instruction includes that temperature indicates the average kinetic energy of particles, while heat is the energy transfer due to temperature difference.

Clarification 2: Instruction includes using particle-level models to explain thermal energy and motion. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.2 Relate temperature to particle motion.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting particle-level models for solids, liquids, and gases.

Clarification 2: Instruction includes using particle-level models to explain thermal energy and motion. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.3 Calculate heat transfer during temperature change.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship $q=mc\Delta T$ with correct positive or negative sign conventions.

Clarification 2: Instruction includes the use of coffee cup calorimetry to determine specific heat or energy change during a temperature change.

Clarification 3: Instruction includes interpreting heating and cooling curves during segments where temperature changes without a phase change.

Clarification 4: Instruction includes applying dimensional analysis and algebraic reasoning. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 5: Instruction includes designing and conducting calorimetry investigations and analyzing data. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.4 Calculate heat transfer during phase change.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship q=mL for phase changes with correct positive or negative sign conventions.

Clarification 2: Instruction includes the use of coffee cup calorimetry to determine latent heat during melting, freezing, vaporization, or condensation.

Clarification 3: Instruction includes interpreting heating and cooling curves at plateaus where phase change occurs without a change in temperature.

Clarification 4: Instruction includes applying dimensional analysis and algebraic reasoning. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes designing and conducting calorimetry investigations and analyzing data. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.5 Describe conduction and its applications.

Benchmark Clarifications:

Clarification 1: Instruction includes particle-level explanations of thermal conduction in solids and the distinction between thermal conductors and thermal insulators.

Clarification 2: Instruction includes real-world design implications such as building envelopes, including insulation, window glazing, and material selection to manage heat transfer.

Clarification 3: Instruction includes using models to explain conduction. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EN.3.6 Describe convection and its applications.

Benchmark Clarifications:

Clarification 1: Instruction includes convection in fluids, density driven circulation, and the difference between natural convection and forced convection.

Clarification 2: Instruction includes applications such as household heating and cooling, ocean and atmospheric circulation, and thermal management in engineering systems.

Clarification 3: Instruction includes using models to explain convection. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.7 Describe radiation and its applications.

Benchmark Clarifications:

Clarification 1: Instruction includes thermal radiation as energy transfer by electromagnetic waves and factors that affect radiative exchange such as temperature, surface properties, and emissivity.

Clarification 2: Instruction includes solar energy collection and everyday examples of radiative heat transfer such as sunlight warming surfaces and radiant heat from a fire.

Clarification 3: Instruction includes using models to explain radiation. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.8 Explain endothermic processes using enthalpy changes.

Benchmark Clarifications:

Clarification 1: Instruction includes explaining that breaking chemical bonds absorbs energy and contributes to a positive value of ΔH.

Clarification 2: Instruction includes interpreting signs and relative magnitudes of enthalpy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 3: Instruction includes interpreting energy diagrams and thermochemical representations. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.3.9 Explain exothermic processes using enthalpy changes.

Benchmark Clarifications:

Clarification 1: Instruction includes explaining that forming chemical bonds releases energy and contributes to a negative value of ΔH.

Clarification 2: Instruction includes interpreting signs and relative magnitudes of enthalpy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes interpreting energy diagrams and thermochemical representations. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.4 Explain how electric potential difference, electrical power, and energy transfer in direct current circuits describe the behavior and efficiency of electrical systems and apply quantitative relationships to relate energy per unit charge, compute power, and analyze energy delivery and dissipation in series and parallel circuits.

SC.912.EN.4.1 Relate electric potential difference (voltage) to energy per unit charge.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship V=w/q.

Clarification 2: Instruction includes interpreting voltage as energy transferred per unit charge in a circuit.

Clarification 3: Instruction includes applying mathematical relationships to analyze circuits.

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Clarification 4: Instruction includes applying algebraic reasoning and unit analysis to relate voltage, energy, and charge. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using circuit diagrams and conceptual models to represent energy transfer per unit charge. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes interpreting measured data to relate voltage to energy transfer in electrical systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.4.2 Compute electrical power.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationships P=VI, P=I^2 R, and P=V^2/R.

Clarification 2: Instruction includes household energy usage in kilowatt hours and estimating energy cost from power and time.

Clarification 3: Instruction includes applying algebraic reasoning, proportional relationships, and dimensional analysis to solve for power, current, voltage, or resistance. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using circuit diagrams and graphical representations to model relationships among voltage, current, resistance, and power. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes collecting and analyzing data from electrical systems to relate power to energy use and cost. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.4.3 Analyze energy transfer in simple direct-current circuits.

Benchmark Clarifications:

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Clarification 1: Instruction includes tracing energy delivered by sources and energy dissipated by resistors in series and parallel circuits.

Clarification 2: Instruction includes efficiency concepts in electrical systems by comparing useful energy output to total energy input.

Clarification 3: Instruction includes analyzing quantitative relationships among voltage, current, resistance, and energy transfer. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using circuit diagrams and energy flow models to trace energy transfer and dissipation in circuits. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using experimental data to analyze energy transfer and efficiency in electrical systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.5 Explain how energy is converted and transferred in common systems and devices, and apply efficiency calculations, energy flow representations, and calorimetry to quantify specific heat and enthalpy changes and to evaluate useful output versus losses to the surroundings.

SC.912.EN.5.1 Explain efficiency in energy conversions.

Benchmark Clarifications:

Clarification 1: Instruction includes calculating efficiency using η=E_"useful" /E_"input" ×100%.

Clarification 2: Instruction includes interpreting Sankey diagrams and energy flow diagrams.

Clarification 3: Instruction includes applying proportional reasoning and unit analysis when calculating efficiency. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes using models such as Sankey diagrams and energy flow diagrams to represent efficiency. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.5.2 Describe energy conversion in common systems and devices.

Benchmark Clarifications:

Clarification 1: Instruction includes identifying the forms of energy entering a system, the transformations that occur within the system, and the forms of energy leaving the system.

Clarification 2: Instruction includes describing energy conversion pathways in devices such as motors, lightbulbs, heating systems, cooling systems, and simple engines, with attention to useful energy output and energy lost to the surroundings.

Clarification 3: Instruction includes using energy flow diagrams and system models to visualize how energy is converted and transferred within devices and systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing data and observations to evaluate efficiency and energy loss. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.5.3 Apply calorimetry to determine specific heat.

Benchmark Clarifications:

Clarification 1: Instruction includes designing and conducting calorimetry experiments to measure temperature change, collect data, and apply significant figures appropriately.

Clarification 2: Instruction includes calculating specific heat from calorimetry data and analyzing percent error and sources of uncertainty.

Clarification 3: Instruction includes applying algebraic reasoning and dimensional analysis to calorimetry calculations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes designing and refining calorimetry investigations and evaluating sources of errors. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.5.4 Apply calorimetry to determine enthalpy change for a process.

Benchmark Clarifications:

Clarification 1: Instruction includes solution and reaction calorimetry at an introductory level, including temperature measurement, energy accounting, and proper recording of data.

Clarification 2: Instruction includes calculating enthalpy change using calorimetry data and interpreting results in the context of endothermic or exothermic processes.

Clarification 3: Instruction includes using mathematical relationships to calculate enthalpy change. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using energy diagrams to represent enthalpy changes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes analyzing calorimetry data to construct evidence-based explanations of energy changes. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.6 Explain how the First and Second Laws of Thermodynamics govern energy, work, and entropy in closed systems, and apply qualitative heat engine efficiency limits and pressure–volume diagrams to identify work and thermodynamic process types.

SC.912.EN.6.1 Apply the First Law of Thermodynamics to closed systems.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship $\Delta U=Q-W$ with positive or negative sign conventions.

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Clarification 2: Instruction includes qualitative energy accounting in processes such as compression and expansion.

Clarification 3: Instruction includes applying algebraic reasoning to analyze energy changes in thermodynamic systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using system models to represent energy flow and internal energy changes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.6.2 Describe the Second Law of Thermodynamics and the concept of entropy.

Benchmark Clarifications:

Clarification 1: Instruction includes that total entropy increases in real processes and that some energy becomes less available for useful work.

Clarification 2: Instruction includes examples of irreversible processes that illustrate entropy increase.

Clarification 3: Instruction includes using models to represent entropy changes and energy distribution in systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes examining historical developments that contributed to scientific understanding of the Second Law of Thermodynamics. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.6.3 Describe heat-engine efficiency at a quantitative level.

Benchmark Clarifications:

Clarification 1: Instruction includes the maximum efficiency expression $n_{max}=1-T_c/T_h$ as an upper limit when temperature values are given.

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Clarification 2: Instruction includes the differences between ideal engine efficiency and real engine efficiency.

Clarification 3: Instruction includes applying mathematical relationships to describe efficiency limits. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using models to represent energy transformations in heat engines. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.6.4 Interpret pressure-volume diagrams to identify work and thermodynamic process types.

Benchmark Clarifications:

Clarification 1: Instruction includes recognizing that work corresponds to the area under a pressure–volume curve.

Clarification 2: Instruction includes identifying isobaric, isochoric, isothermal, and adiabatic processes qualitatively and excludes calculus-based derivations.

Clarification 3: Instruction includes interpreting graphical relationships such as area under curves to represent work. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using graphical models to represent thermodynamic processes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.7 Compare major energy sources, storage methods, and energy technologies and explain how energy systems generate, store, transmit, distribute, and manage energy to meet changing demand, including evaluation of availability, reliability, efficiency, environmental impacts, risks, benefits, and societal considerations.

SC.912.EN.7.1 Compare major energy sources.

Benchmark Clarifications:

Clarification 1: Instruction includes fossil fuels, nuclear fission, solar, wind, hydroelectric, geothermal, and biomass energy sources.

Clarification 2: Instruction includes evaluating availability, reliability, environmental impacts, general advantages, and limitations.

Clarification 3: Instruction includes interpreting and comparing data related to availability, intermittency, and environmental impacts. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing data to evaluate trade-offs among energy sources. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.7.2 Compare energy storage methods.

Benchmark Clarifications:

Clarification 1: Instruction includes chemical storage in batteries, gravitational storage in pumped hydroelectric systems, and thermal storage systems.

Clarification 2: Instruction includes analyzing trade-offs related to capacity, efficiency, and response time.

Clarification 3: Instruction includes evaluating relationships among capacity, efficiency, and response time. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using system models and energy flow diagrams to compare energy storage methods. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes analyzing data to compare energy storage methods. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.7.3 Describe how electricity is generated, transmitted, and distributed.

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Benchmark Clarifications:

Clarification 1: Instruction includes generation in power plants, voltage transformation, and transmission and distribution through the electrical grid.

Clarification 2: Instruction includes qualitative descriptions of line losses and the need for system stability.

Clarification 3: Instruction includes using models to represent energy flow in generation, transmission, and distribution systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes examining historical developments that contributed to scientific understanding of technology associated with the use of electricity. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.7.4 Describe how electricity is managed to meet changing demand.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of energy storage, peak-shaving strategies, and dispatchable generation.

Clarification 2: Instruction includes demand-side management such as load shifting and efficiency programs.

Clarification 3: Instruction includes using system models to represent relationships among energy demand, generation, storage, and distribution. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing data to evaluate strategies for managing energy demand. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.7.5 Analyze the operation, benefits, limitations, risks, and applications of nuclear energy systems.

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Example: Compare nuclear power with fossil fuel and renewable energy systems.

Example: Evaluate trade-offs associated with different energy generation technologies.

Benchmark Clarifications:

Clarification 1: Instruction includes fission reactors, chain reactions, moderators, control rods, shielding, cooling systems, and reactor safety features.

Clarification 2: Instruction includes radioactive waste management, fuel cycles, and considerations associated with the long-term storage and disposal of radioactive materials.

Clarification 3: Instruction includes evaluating relationships among energy production, reliability, efficiency, environmental impacts, and safety considerations associated with nuclear energy systems.

Clarification 4: Instruction includes comparing energy generation technologies using scientific evidence and quantitative data. Refer to Mathematics Skills Supporting Mastery of 9–12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using system models to represent energy transfer, reactor operation, and interactions among components of nuclear energy systems. Refer to Modeling Skills Supporting Mastery of 9–12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes analyzing data and evidence to evaluate benefits, limitations, risks, and trade-offs associated with nuclear energy systems. Refer to Laboratory Practices Supporting Mastery of 9–12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.7.6 Evaluate environmental, economic, societal, and public health considerations associated with the use of nuclear technologies.

Benchmark Clarifications:

Clarification 1: Instruction includes energy security, reliability of energy supply, environmental impacts, waste management, and resource use associated with nuclear technologies.

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Clarification 2: Instruction includes economic considerations such as construction, operation, maintenance, fuel, and decommissioning costs.

Clarification 3: Instruction includes public health and safety considerations related to radiation exposure, accident prevention, and radiation protection practices.

Clarification 4: Instruction includes evaluating benefits, limitations, risks, and trade-offs associated with nuclear technologies using scientific evidence and data.

Clarification 5: Instruction includes interpreting and comparing quantitative data related to environmental impacts, energy production, costs, safety, and waste management. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes analyzing evidence from case studies and datasets to evaluate trade-offs associated with nuclear technologies. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.8 Apply thermodynamic, electromagnetic, gravitational, and quantum relationships to analyze spontaneity and equilibrium, quantify energy stored in electric and magnetic fields, describe gravitational potential beyond the near-Earth approximation, and explain photon energy and the photoelectric effect.

SC.912.EN.8.1 Explain how energy and entropy influence spontaneity and equilibrium in physical and chemical systems.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship among Gibbs Free Energy, enthalpy, entropy, and temperature and qualitative interpretation of the signs of Gibbs Free Energy, enthalpy, and entropy.

Clarification 2: Instruction includes the relationship between Gibbs Free Energy and equilibrium at a conceptual or algebraic level.

Clarification 3: Instruction includes interpreting mathematical relationships and graphical models to explain spontaneity and equilibrium. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes using energy diagrams and thermodynamic models to represent spontaneity and equilibrium. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.8.2 Analyze energy storage in electric and magnetic fields.

Benchmark Clarifications:

Clarification 1: Instruction includes energy stored in electric fields associated with capacitors and represented by the relationship E=1/2 CV^2.

Clarification 2: Instruction includes energy stored in magnetic fields associated with inductors and represented by the relationship E=1/2 LI^2 , including qualitative energy exchange in LC systems.

Clarification 3: Instruction includes interpreting mathematical relationships describing energy storage in electric and magnetic fields and relationships among capacitance, inductance, charge, current, voltage, and stored energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using circuit models, field models, and graphical representations to explain energy storage and transfer in electric and magnetic fields. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes collecting, analyzing, or interpreting data from investigations involving capacitive or inductive energy storage. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.8.3 Describe gravitational potential energy beyond the near-Earth approximation.

Benchmark Clarifications:

Clarification 1: Instruction includes gravitational potential energy U=-GMm/r.

Clarification 2: Instruction includes qualitative implications for escape velocity and orbital energy while excluding orbital mechanics derivations.

Clarification 3: Instruction includes interpreting relationships between distance, mass, and gravitational energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using models to represent gravitational systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of gravitation, orbital motion, and gravitational energy. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EN.8.4 Explain photon energy and the photoelectric effect.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship E=hf and the concept of a material work function.

Clarification 2: Instruction includes distinguishing how changes in intensity and frequency affect electron emission.

Clarification 3: Instruction includes applying relationships between frequency and energy using mathematical models. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using models to explain photon energy and electron emission. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of photon energy and the photoelectric effect. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Proposed DRAFT Standards

How energy is transformed, transferred, and conserved within and among the geosphere, hydrosphere, atmosphere, and biosphere, shaping Earth's processes, patterns, resources, and hazards.

Grades 9-12

SC.912.EE.1 Explain how energy moves and changes in the lithosphere, hydrosphere, and atmosphere; describe how heat is transferred by conduction, convection, and radiation; and use diagrams to show how energy flows and why some energy is always lost as heat.

SC.912.EE.1.1 Identify and classify energy forms in Earth's spheres.

Benchmark Clarifications:

Clarification 1: Instruction includes kinetic, gravitational, thermal, chemical, nuclear, light, sound, radiant, solar, geothermal and electrical energy forms situated within Earth system processes.

Clarification 2: Instruction includes where each energy form is stored or observed in the geosphere, hydrosphere, atmosphere, and biosphere.

Clarification 3: Instruction includes using models to classify and represent energy forms in Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.1.2 Explain conservation of energy and track transformations across Earth spheres.

Benchmark Clarifications:

Clarification 1: Instruction includes recognizing that energy cannot be created or destroyed but can change form, and that total energy is conserved within defined systems even as energy crosses Earth-system boundaries.

Clarification 2: Instruction includes tracing energy as it moves across spheres within Earth's systems.

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Clarification 3: Instruction includes tracing multi-step transformations through Earth systems.

Clarification 4: Instruction includes using energy diagrams, flow models, and verbal explanations to follow energy transformations and energy losses due to non-conservative processes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of the conservation of energy. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.1.3 Identify conduction, convection, and radiation in geosphere-hydrosphere-atmosphere interactions.

Benchmark Clarifications:

Clarification 1: Instruction includes defining conduction, convection, and radiation as primary mechanisms of energy transfer.

Clarification 2: Instruction includes examples of each mechanism in natural and human Earth systems.

Clarification 3: Instruction includes observable phenomena affected by energy transfer, such as sea breezes, thunderstorms, ocean upwelling, and temperature differences between the geosphere and hydrosphere.

Clarification 4: Instruction includes using diagrams and system models to represent conduction, convection, and radiation in Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.1.4 Interpret energy bar diagrams, flow diagrams, and qualitative efficiency.

Benchmark Clarifications:

Clarification 1: Instruction includes reading and constructing energy bar charts, Sankey diagrams, and energy flow diagrams.

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Clarification 2: Instruction includes interpreting diagrams in the context of Earth's energy budget, ecosystem energy flow, water cycle, and human energy systems.

Clarification 3: Instruction includes efficiency examples such as atmospheric convection transferring only a fraction of absorbed solar energy, photosynthesis converting a fraction of incoming solar energy into chemical energy, and heat loss in building or ocean-atmosphere heat exchange.

Clarification 4: Instruction includes that energy transformations are never one hundred percent efficient and Earth processes involve useful energy, waste heat, and dissipation.

SC.912.EE.2 Explain how work, kinetic energy, potential energy, and the work–energy relationships operate in real Earth systems, including how friction, drag, turbulence, gravity, and elastic forces affect energy transfer and shape Earth's landscapes, natural hazards, and the movement of matter in the geosphere, hydrosphere, and atmosphere.

SC.912.EE.2.1 Calculate work in real-world Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes calculations of work using $W=Fd\cos\theta$ and power $P=W/t$ in the appropriate International System of units (SI) and in natural and human Earth system processes.

Clarification 2: Instruction includes applying work and power concepts to quantify energy transfer in geosphere, hydrosphere, and atmosphere processes.

Clarification 3: Instruction includes applying algebraic reasoning, dimensional analysis, and unit conversions to calculate work and power in Earth-system contexts. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.2.2 Compute kinetic and potential energy in real-world Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes calculations for kinetic energy (KE=1/2 mv^2) and gravitational potential energy (U_g=mgh) in the appropriate International System of Units (SI) and in natural and human Earth system processes.

Clarification 2: Instruction includes how kinetic and potential energy influence landscape change, erosion, extreme weather, and energy resources.

Clarification 3: Instruction includes applying mathematical relationships and interpreting graphical representations of kinetic and potential energy changes in Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using graphs and energy models to represent kinetic and potential energy changes in Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.2.3 Apply the work–energy theorem and conservation of mechanical energy with non-conservative forces.

Benchmark Clarifications:

Clarification 1: Instruction includes applying the work–energy theorem to interpret how non conservative forces shape Earth's landforms and dissipate natural energy.

Clarification 2: Instruction includes applying mathematical relationships to analyze work-energy relationships in Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes using energy-flow diagrams and graphical models to represent conservation of mechanical energy and non-conservative energy losses. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.2.4 Analyze gravitational and elastic potential energy in physical Earth processes.

Benchmark Clarifications:

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Clarification 1: Instruction includes gravitational and elastic potential energy in Earth processes.

Clarification 2: Instruction includes changes in gravitational and elastic energy related to earthquakes, erosion, topography, and natural hazard processes.

Clarification 3: Instruction includes interpreting relationships among height, deformation, and stored energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using models to represent gravitational and elastic energy changes in Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.3 Explain how heat and temperature differ; how thermal energy is transferred by conduction, convection, and radiation; how heat is gained or lost during warming, cooling, and phase changes; and how these energy processes drive changes in Earth's land, water, and air.

SC.912.EE.3.1 Distinguish heat from temperature using particle motion models.

Benchmark Clarifications:

Clarification 1: Instruction includes that temperature measures the average kinetic energy of particles, while heat is the transfer of energy from warmer to cooler objects or systems.

Clarification 2: Instruction includes particle motion models to show how heat flows between the land, water, and air such as air warming after contacting a sun heated surface, or ocean water absorbing heat that drives evaporation and storms. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.3.2 Calculate heat transfer during temperature and phase changes.

Benchmark Clarifications:

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Clarification 1: Instruction includes calculating thermal energy changes in real Earth contexts such as warming or cooling of land, water, and air; evaporation and condensation in the water cycle; melting and freezing in glaciers or seasonal snow; and interpreting how different materials require different amounts of heat due to specific heat capacity.

Clarification 2: Instruction includes applying dimensional analysis, proportional reasoning, and algebraic relationships when calculating thermal energy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes analyzing temperature and calorimetry data from investigations of Earth materials. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.3.3 Describe conduction, convection, and radiation in Earth systems and engineering contexts.

Benchmark Clarifications:

Clarification 1: Instruction includes identifying how each mechanism of heat transfer operates in natural systems such as ground heating air at the surface and heat moving through soil or rock (conduction); rising warm air in thunderstorms, ocean circulation driven by density differences, and mantle convection associated with internal heat transfer; sunlight warming Earth's surface and Earth releasing infrared radiation back into space (radiation).

Clarification 2: Instruction includes human-engineered contexts such as insulation, solar collectors, and heating/cooling systems.

SC.912.EE.3.4 Interpret heating and cooling curves, including plateaus during phase changes.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting heating and cooling curves to relate temperature changes and phase change plateaus to Earth processes such as energy absorbed during melting of ice or evaporation that drives weather and storms; energy released during freezing or condensation in cloud and storm formation; and understanding

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why large bodies of water warm and cool slowly due to high heat capacity and phase change energy.

SC.912.EE.4 Explain how thermal energy and enthalpy changes in Earth materials drive endothermic and exothermic processes, phase changes, dissolution, and geochemical reactions by interpreting enthalpy diagrams; applying calorimetry to Earth materials; analyzing energy changes in the hydrologic cycle and weathering; and connecting these transformations to storm systems, climate patterns, and landscape evolution.

SC.912.EE.4.1 Explain endothermic and exothermic processes using enthalpy diagrams.

Benchmark Clarifications:

Clarification 1: Instruction includes using enthalpy diagrams to explain Earth system processes such as melting ice and evaporating water (endothermic absorption of heat from the environment); freezing and condensation in clouds and storms (exothermic release of heat to the atmosphere); chemical weathering reactions that may absorb or release energy depending on the minerals involved; and combustion of fossil fuels (exothermic reaction releasing stored chemical energy).

Clarification 2: Instruction includes the connection between enthalpy changes and energy movement in the land, water, and air.

Clarification 3: Instruction includes examining historical developments that contributed to scientific understanding of endothermic and exothermic processes. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.4.2 Apply calorimetry to determine specific heat and enthalpy changes.

Benchmark Clarifications:

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Clarification 1: Instruction includes using calorimetry to measure temperature changes and calculate the specific heat of Earth materials: water, soils, sands, and rock.

Clarification 2: Instruction includes enthalpy changes during temperature changes or phase changes.

Clarification 3: Instruction includes the application of calorimetry concepts to real Earth contexts such as why water heats and cools slowly (high specific heat), how rock type affects surface heating (urban heat island effect), and the energy involved in melting or freezing of ice as it pertains to climate and weather patterns.

Clarification 4: Instruction includes designing, conducting, and evaluating calorimetry investigations involving Earth materials. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.4.3 Analyze phase transitions and dissolution processes relevant to Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes the energy changes involved in phase transitions in the water cycle: melting, freezing, evaporation, condensation, and sublimation.

Clarification 2: Instruction includes the energy changes involved in dissolution processes such as minerals dissolving in water, salts entering or leaving seawater, and chemical interactions affecting groundwater.

Clarification 3: Instruction includes how these processes drive Earth system phenomena including storm formation powered by evaporation and condensation; glacial melting and formation affecting sea level and climate; and dissolution and precipitation of minerals in caves, oceans, and soils, shaping landscapes.

SC.912.EE.4.4 Connect enthalpy and energy transformations to storm systems, weathering, and geochemistry.

Benchmark Clarifications:

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Clarification 1: Instruction includes that these energy transformations drive climate patterns, landscape evolution, and Earth's chemical cycles.

SC.912.EE.5 Explain how electrical energy is generated, transferred, and transformed in Earth systems by relating electric potential difference to energy per charge, computing electrical power in Earth connected technologies, analyzing energy transfer and dissipation in circuits, and connecting these concepts to natural processes such as lightning and human systems including solar energy and the electrical grid.

SC.912.EE.5.1 Relate electric potential difference to energy per unit charge in Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes electric potential difference in natural Earth processes such as atmospheric electrification, lightning, and naturally occurring electric potential differences associated with Earth materials and groundwater systems.

Clarification 2: Instruction includes the connection of voltage to how energy per charge drives electrical interactions in the atmosphere, geosphere, and engineered Earth systems.

SC.912.EE.5.2 Compute electrical power in relationship to Earth-connected systems.

Benchmark Clarifications:

Clarification 1: Instruction includes Earth-connected systems such as solar panels, wind turbines, hydropower and power grids.

Clarification 2: Instruction includes how electrical power supports human uses of Earth's energy resources and how environmental conditions affect generation efficiency.

SC.912.EE.5.3 Analyze energy transfer and dissipation in simple circuits.

Benchmark Clarifications:

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Clarification 1: Instruction includes analyzing how electrical energy is transferred, transformed, and dissipated in simple circuits: useful energy output, energy losses as heat, and differences in energy transfer.

Clarification 2: Instruction includes Earth-system contexts such as line losses during long-distance power transmission, energy dissipation in lightning channels, and energy distribution in household or community electrical systems.

Clarification 3: Instruction includes collecting and analyzing data to investigate electrical energy transfer and dissipation. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.5.4 Connect electrical energy concepts to lightning, solar energy, and grid systems.

Benchmark Clarifications:

Clarification 1: Instruction includes how electrical energy connects natural atmospheric processes, Earth-based energy resources, and human-engineered distribution systems.

Clarification 2: Instruction includes using models and evidence to explain relationships among electrical generation, transmission, storage, and Earth-system processes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes examining historical developments that contributed to scientific understanding of electrification, power generation, and transmission systems. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.6 Explain how energy from renewable and nonrenewable Earth resources is converted, transferred, and stored to meet human needs by comparing source availability and environmental impacts, calculating and interpreting efficiency, describing input to output conversion pathways, including losses, in common devices, and evaluating storage options and electric grid distribution and demand management strategies.

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SC.912.EE.6.1 Compare renewable and nonrenewable energy sources, availability, and environmental impacts.

Benchmark Clarifications:

Clarification 1: Instruction includes renewable and nonrenewable energy sources in terms of resource origin within Earth systems, spatial availability, temporal availability and capacity factors.

Clarification 2: Instruction includes evaluating impacts across Earth's spheres: atmosphere, hydrosphere, geosphere, and biosphere.

Clarification 3: Instruction includes regional availability of energy sources and trade-offs among reliability, cost and environmental effects.

Clarification 4: Instruction includes analyzing datasets to evaluate trade-offs among energy sources. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.6.2 Calculate efficiency in Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes calculating device or system efficiency for Earth-connected technologies such as turbines, PV modules, heat pumps, and combustion systems.

Clarification 2: Instruction includes relating efficiency to Earth-system constraints such as thermodynamic limits, environmental conditions, and a systems perspective that recognizes cumulative losses and opportunities for efficiency gains and waste-heat recovery.

Clarification 3: Instruction includes applying proportional reasoning, percentages, and unit analysis when calculating efficiency. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.6.3 Describe energy conversion pathways in common systems and devices.

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Benchmark Clarifications:

Clarification 1: Instruction includes identifying an input to transformation to output (with losses) for devices that interface with Earth systems such as wind turbines, hydropower systems, photovoltaic systems, engines, boilers, and HVAC systems.

Clarification 2: Instruction includes using energy flow diagrams and Sankey charts to visualize useful output vs. losses.

Clarification 3: Instruction includes how site conditions such as wind shear profiles, solar angle, and ambient temperature shape conversion effectiveness and reliability.

Clarification 4: Instruction includes using Sankey diagrams, energy-flow diagrams, and system models to represent energy transformations and losses. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.6.4 Compare major energy storage methods and describe grid distribution and demand management.

Benchmark Clarifications:

Clarification 1: Instruction includes storage options such as chemical, gravitational, thermal, and mechanical storage methods based on capacity, round trip efficiency, response time, lifespan, and earth resource dependencies.

Clarification 2: Instruction includes describing grid generation, transmission, and distribution and demand management strategies.

Clarification 3: Instruction includes using system models to represent interactions among generation, storage, transmission, distribution, and demand. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.7 Explain how advanced energy concepts govern spontaneity, energy storage, orbital motion, and electromagnetic interactions in Earth systems; and describe how these principles support processes such as weathering, lightning, satellite motion, solar energy conversion, and remote sensing.

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Proposed DRAFT Standards

SC.912.EE.7.1 Explain how energy and entropy influence the spontaneity and equilibrium of Earth-system processes.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting Gibbs Free Energy conceptually as a measure of whether a process is likely to occur spontaneously.

Clarification 2: Instruction includes explaining relationships among energy, entropy, and equilibrium in geochemical and biogeochemical systems.

Clarification 3: Instruction includes interpreting mathematical relationships describing spontaneity and equilibrium. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes interpreting Gibbs Free Energy diagrams and models. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.7.2 Analyze energy stored in electric and magnetic fields in Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes relating field energy to components like capacitors and inductors, and qualitatively to electromagnetic waves transporting energy through the atmosphere and space.

Clarification 2: Instruction includes Earth-system connections such as lightning and atmospheric electric fields, magnetosphere-solar wind interactions, induction in power systems during geomagnetic storms, remote sensing, and communications relying on electromagnetic field propagation.

Clarification 3: Instruction includes interpreting mathematical relationships describing energy stored in electric and magnetic fields and relationships among charge, current, voltage, inductance, capacitance, and stored energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes using field models, circuit models, and graphical representations to explain energy storage and transfer in electric and magnetic fields. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.7.3 Describe gravitational potential energy beyond the near-Earth approximation.

Benchmark Clarifications:

Clarification 1: Instruction includes escape velocity, orbital energy, and energy changes for satellites observing the Earth system.

Clarification 2: Instruction includes connecting gravitational energy to tides, orbital transfer energy for Earth-observing satellites, and implications for global positioning, climate monitoring, and disaster response.

Clarification 3: Instruction includes interpreting mathematical relationships among distance, mass, and gravitational potential energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using models to represent gravitational systems, orbital motion, and energy changes associated with Earth-observing satellites. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of gravitation, orbital motion, and satellite technologies. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EE.7.4 Explain photon energy and the photoelectric effect.

Benchmark Clarifications:

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Clarification 1: Instruction includes relating photon energy to wavelength and frequency, explaining threshold frequency in the photoelectric effect, and connecting to material work function and bandgap.

Clarification 2: Instruction includes Earth-system applications: solar photovoltaics converting solar radiation to electricity; spectroscopy and remote sensing using specific wavelengths to infer atmospheric composition, ocean color, surface temperature, and vegetation health; and radiation balance in Earth's energy budget.

Clarification 3: Instruction includes applying relationships among wavelength, frequency, and photon energy and interpreting electromagnetic spectra. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using spectral models, photon models, and electromagnetic-spectrum representations to explain photon energy, solar photovoltaics, spectroscopy, and remote sensing. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of photon energy and the photoelectric effect. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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The Science of Energy in Space Systems

How energy is transformed, conserved, and managed in the space environment; governing planetary motion, spacecraft behavior, and the operation of space-based technologies.

Grades 9-12

SC.912.ES.1 Explain how energy exists, is conserved, and is transferred in space across radiant, mechanical, gravitational, thermal, electrical, chemical, and particle forms and how these forms of energy interact in planetary systems and spacecraft.

SC.912.ES.1.1 Identify and classify energy forms in space systems.

Benchmark Clarifications:

Clarification 1: Instruction includes radiant, mechanical, gravitational potential, thermal, electrical, chemical, nuclear, and particle kinetic energy forms situated within space system processes.

Clarification 2: Instruction includes where each form is observed: stars and spectra, orbits, arrays and batteries, and plasmas.

Clarification 3: Instruction includes using models to classify and represent energy forms in space systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.1.2 Explain conservation of energy and track transformations in space systems.

Benchmark Clarifications:

Clarification 1: Instruction includes energy conservation in closed systems and transformations among forms.

Clarification 2: Instruction includes using energy bar charts, Sankey diagrams, and flow models to track transformations in space systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes examining historical developments that contributed to scientific understanding of energy conservation and energy transformations. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.1.3 Identify radiation, conduction, and convection pathways relevant to space.

Benchmark Clarifications:

Clarification 1: Instruction includes that radiation dominates in a vacuum; conduction occurs through structures; and convection is negligible in space.

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Clarification 2: Instruction includes using models to represent energy-transfer pathways in space environments. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.1.4 Interpret energy bar and flow (Sankey) diagrams for space systems.

Benchmark Clarifications:

Clarification 1: Instruction includes reading and constructing energy flow diagrams for spacecraft.

Clarification 2: Instruction includes qualitative efficiency and unavoidable waste heat management.

Clarification 3: Instruction includes interpreting relationships among energy input, useful output, and losses. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.2 Explain how work, kinetic and gravitational potential energy, and mechanical energy conservation apply to orbits, transfers, and gravity assists, including how non-conservative effects change spacecraft energy.

SC.912.ES.2.1 Calculate work and power for spaceflight scenarios.

Benchmark Clarifications:

Clarification 1: Instruction includes $W=FD\cos\theta$ and $P=W/t$ in SI units for thrust events and attitude maneuvers.

Clarification 2: Instruction includes estimating power and work in aerobraking and in reaction-control adjustments.

Clarification 3: Instruction includes applying algebraic reasoning, dimensional analysis, and unit conversion when calculating work and power. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.2.2 Compute kinetic and gravitational potential energy in orbits.

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Benchmark Clarifications:

Clarification 1: Instruction includes KE=1/2 mv^2 and U=-GMm/r for total orbital energy concepts.

Clarification 2: Instruction includes comparing Low Earth Orbit (LEO), Medium-Earth Orbit (MEO), and Geostationary Orbit (GEO) energies and how changes in r and v inform Δv budgets and mission design.

Clarification 3: Instruction includes applying mathematical relationships and interpreting graphical representations of energy changes in orbital systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.2.3 Apply work-energy relations to orbital changes and gravity assists.

Benchmark Clarifications:

Clarification 1: Instruction includes qualitative energy accounting for Hohmann and bi-elliptic transfers and gravity assists.

Clarification 2: Instruction includes using graphical and conceptual models to represent orbital transfers and gravity assists. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.2.4 Analyze non-conservative effects on spacecraft energy.

Benchmark Clarifications:

Clarification 1: Instruction includes atmospheric drag (LEO), solar radiation pressure, third-body perturbations, and thrust energy sinks and sources.

Clarification 2: Instruction includes using models to represent energy changes associated with drag, radiation pressure, and orbital perturbations. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.ES.3 Explain how heat and temperature differ, quantify heat transfer in space relevant materials, describe spacecraft thermal control strategies, and interpret heating and cooling behaviors in orbital and lander environments.

SC.912.ES.3.1 Distinguish between heat and temperature using particle and radiation models.

Benchmark Clarifications:

Clarification 1: Instruction includes average kinetic energy (temperature) and energy transfer (heat).

Clarification 2: Instruction includes eclipse and day-night swings; albedo and emissivity effects; and hot and cold case analyses.

Clarification 3: Instruction includes using particle and radiation models. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.3.2 Calculate heat transfer and thermal capacity for space materials.

Benchmark Clarifications:

Clarification 1: Instruction includes how to calculate heat transfer using $q=mc\Delta T$ for each part of the system.

Clarification 2: Instruction includes how to account for heat transfer by radiation using $E=\sigma T^{(4)}$.

Clarification 3: Instruction includes applying dimensional analysis and algebraic relationships to calculate thermal energy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.3.3 Describe thermal control strategies in spacecraft.

Benchmark Clarifications:

Clarification 1: Instruction includes the methods spacecraft use to control temperature

such as radiators, adjustable louvers, multi-layer insulation (MLI), heat pipes or heat straps, and sunshields.

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Clarification 2: Instruction includes how engineers design paths for heat to move through spacecraft (conduction).

Clarification 3: Instruction includes using system models to represent spacecraft thermal-management systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.3.4 Interpret heating and cooling profiles for orbital and lander scenarios.

Benchmark Clarifications:

Clarification 1: Instruction includes thermal time constants, eclipse transients, entry heating curves, and phase-change materials for buffering.

Clarification 2: Instruction includes interpreting graphical representations of thermal behavior over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.4 Describe and evaluate how enthalpy, calorimetry, and phase transitions govern energy flow in space environments and influence material behavior, volatile transport, and mission operations.

SC.912.ES.4.1 Explain endothermic and exothermic processes with enthalpy diagrams.

Benchmark Clarifications:

Clarification 1: Instruction includes explaining endothermic and exothermic processes associated with chemical reactions, volatile sublimation, and material phase transitions in space environments. Clarification 2: Instruction includes links to volatile transport, plume-surface interactions, and in-situ resource utilization (ISRU) steps.

SC.912.ES.4.2 Apply calorimetry to determine the energy absorbed or released by space materials.

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Benchmark Clarifications:

Clarification 1: Instruction includes applying specific-heat and latent-heat values to analyze how propellants and spacecraft parts store and manage heat.

Clarification 2: Instruction includes boil-off budgets and ISRU energy requirements.

Clarification 3: Instruction includes applying mathematical relationships to calculate thermal-energy and enthalpy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes designing and evaluating calorimetry investigations. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.4.3 Analyze phase transitions and sublimation in space.

Benchmark Clarifications:

Clarification 1: Instruction includes how water and carbon dioxide can change between solid and gas in very cold, shadowed craters; in the glowing clouds around comets; and within thin frost layers on the surface.

Clarification 2: Instruction includes how phase changes move energy and material from one place to another on small bodies and moons.

SC.912.ES.4.4 Connect enthalpy to mission operations, hazards, and materials by linking thermal energy changes to spacecraft behavior and engineering decisions.

Benchmark Clarifications:

Clarification 1: Instruction includes icing and condensation during ascent; battery heat release; and material compatibility under thermal cycling and vacuum.

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Proposed DRAFT Standards

SC.912.ES.5 Describe how electrical energy is generated, transferred, and used in space systems by explaining electric potential, calculating power, analyzing circuit behavior, and connecting electromagnetic energy to spacecraft operations and space weather.

SC.912.ES.5.1 Explain electric potential difference as the amount of energy given to each unit of charge in space.

Benchmark Clarifications:

Clarification 1: Instruction includes relating electric potential difference to electrical energy transfer in spacecraft power systems, including solar arrays, batteries, and charging systems.

Clarification 2: Instruction includes explaining how spacecraft accumulate electrical charge through interactions with space plasma environments.

Clarification 3: Instruction includes how surfaces on airless worlds can also become electrically charged.

SC.912.ES.5.2 Compute electrical power for space systems.

Benchmark Clarifications:

Clarification 1: Instruction includes arrays, radioisotope thermoelectric generators (RTGs), fuel cells, and load budgets.

Clarification 2: Instruction includes environmental effects on output and efficiency.

Clarification 3: Instruction includes applying mathematical relationships to calculate electrical power. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.5.3 Analyze energy transfer and dissipation in spacecraft circuits.

Benchmark Clarifications:

Clarification 1: Instruction includes regulation and conversion stages, I^2 R losses, and thermal dissipation.

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Clarification 2: Instruction includes radiation-hardening, fault protection, and single-event effects.

Clarification 3: Instruction includes using circuit diagrams, energy-flow diagrams, and system models to represent energy transfer and dissipation in spacecraft circuits. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes analyzing data from spacecraft or simulated electrical systems to evaluate energy transfer, efficiency, and dissipation. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.5.4 Connect electromagnetic (EM) energy to space weather, communications, and power.

Benchmark Clarifications:

Clarification 1: Instruction includes solar storms, magnetosphere-solar wind coupling, antenna link budgets, and wireless power concepts for surface assets.

Clarification 2: Instruction includes examining historical developments that contributed to scientific understanding of electromagnetism, communications technologies, and space-weather interactions. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.6 Explain how spacecraft generate, convert, store, and manage energy by comparing different power sources, calculating system efficiency, explaining how energy moves through power subsystems, and evaluating storage and management strategies needed to keep spacecraft operating safely and reliably in space.

SC.912.ES.6.1 Compare space power sources and the mission trade-offs that are associated with each one.

Benchmark Clarifications:

Clarification 1: Instruction includes space power sources: solar, radioisotope power systems, chemical batteries, and fuel cells.

Clarification 2: Instruction includes how the distance from the Sun, dust, shadow and mission duration affect the availability and usefulness of different space power sources.

Clarification 3: Instruction includes how engineering constraints such as mass, risk, thermal signature, reliability, and planetary-protection influence the selection of space power systems.

SC.912.ES.6.2 Calculate efficiency in power subsystems.

Benchmark Clarifications:

Clarification 1: Instruction includes calculating and comparing efficiencies of solar arrays, power-conditioning systems, batteries, and fuel cells.

Clarification 2: Instruction includes how energy losses stack up through a system (loss chain) and how these losses create heat that spacecraft must get rid of.

Clarification 3: Instruction includes why spacecraft need radiators to release waste heat, and how engineers decide how big those radiators must be.

Clarification 4: Instruction includes applying proportional reasoning, percentages, and unit analysis when calculating efficiency. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.6.3 Describe energy conversion pathways in different space power systems.

Benchmark Clarifications:

Clarification 1: Instruction includes using Sankey diagrams to show where energy goes and understanding how load shedding helps a spacecraft turn off non essential systems to save power. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.ES.6.4 Compare energy storage and power-management strategies in spacecraft.

Benchmark Clarifications:

Clarification 1: Instruction includes comparisons based on: how much energy they hold, how efficient they are, how fast they respond, how long they last, and how well they handle extreme temperatures and radiation.

Clarification 2: Instruction includes explaining how spacecraft manage power through power buses, fault-protection systems, backup systems, and battery state-of-charge planning.

Clarification 3: Instruction includes using system models to represent relationships among generation, storage, power distribution, and energy demand. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.7 Evaluate how fundamental energetic principles govern the behavior of physical systems in space and inform the design, operation, and sustainability of spacecraft and space-based technologies.

SC.912.ES.7.1 Explain how energy and entropy influence spontaneity and equilibrium in space-related physical and chemical systems.

Benchmark Clarifications:

Clarification 1: Instruction includes relationships among Gibbs Free Energy, enthalpy, entropy, and temperature as indicators of spontaneity.

Clarification 2: Instruction includes explaining how spontaneity and equilibrium influence space chemistry and in-situ resource utilization (ISRU).

Clarification 3: Instruction includes interpreting mathematical relationships and graphical models describing spontaneity and equilibrium. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes using thermodynamic diagrams and models to represent spontaneity and equilibrium. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.7.2 Analyze how electric and magnetic fields store and transfer energy and explain how these processes interact with space plasmas to influence currents and the design of spacecraft.

Benchmark Clarifications:

Clarification 1: Instruction includes how electric fields store energy through electric potential and capacitors, and how magnetic fields store energy through magnetic field strength and inductance.

Clarification 2: Instruction includes how energy is transferred by electric and magnetic fields through currents, electromagnetic forces, and field interactions rather than by direct contact.

Clarification 3: Instruction includes how space plasmas respond to electric and magnetic fields, including the motion of charged particles, the formation of currents, and phenomena such as plasma sheaths and spacecraft charging.

Clarification 4: Instruction includes how interactions among fields and space plasmas influence spacecraft design decisions, including grounding strategies, shielding, material selection, and protection of electronics and instruments.

Clarification 5: Instruction includes applying mathematical relationships describing energy stored in electric and magnetic fields and interpreting relationships among field strength, charge, current, and stored energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes using field models, circuit models, and graphical representations to explain energy storage and transfer in electric and magnetic fields. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.ES.7.3 Describe gravitational potential energy beyond the near-Earth approximation.

Benchmark Clarifications:

Clarification 1: Instruction includes gravitational potential energy beyond the near-Earth approximation.

Clarification 2: Instruction includes qualitative implications for escape velocity, orbital energy, and transfers among gravitational systems while excluding orbital mechanics derivations.

Clarification 3: Instruction includes interpreting mathematical relationships among distance, mass, and gravitational potential energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using models to represent gravitational systems, orbital motion, and energy changes associated with spacecraft trajectories. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of gravitation, orbital motion, and spaceflight. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.ES.7.4 Explain photon energy, spectra, and the photoelectric effect.

Benchmark Clarifications:

Clarification 1: Instruction includes photon energy as quantized and directly proportional to frequency and inversely related to wavelength across the electromagnetic spectrum.

Clarification 2: Instruction includes the electromagnetic spectrum from radio waves through gamma rays, including how different regions of the spectrum are produced, detected, and used in scientific and technological applications.

Clarification 3: Instruction includes the photoelectric effect as the emission of electrons from a material when incident photons exceed a threshold frequency, emphasizing the transfer of energy from photons to electrons.

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Clarification 4: Instruction includes applying mathematical relationships among frequency, wavelength, and photon energy and interpreting graphical representations of electromagnetic spectra. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using spectral models, photon models, and electromagnetic spectrum representations to explain photon energy and electromagnetic radiation. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes examining historical developments that contributed to scientific understanding of quantum theory, photon energy, electromagnetic radiation, and the photoelectric effect. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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The Science of Energy in Living Systems

How energy is transformed, transferred, and regulated within living systems to support life from molecules to ecosystems.

Grades 9-12

SC.912.EL.1 Explain how energy exists in multiple forms, is conserved, and is transferred within living systems; and how energy transformations sustain cellular functions and ecological processes.

SC.912.EL.1.1 Identify and classify energy forms in living systems.

Benchmark Clarifications:

Clarification 1: Instruction includes chemical, thermal, mechanical, electrical, radiant, and potential energies stored in gradients.

Clarification 2: Instruction includes where energy is stored or observed: mitochondria, chloroplasts, cytosol, membranes, and tissues.

Clarification 3: Instruction includes using models to classify and represent forms of energy in living systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.1.2 Explain the conservation and transformations of energy in cells and organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes using energy bar charts, Sankey diagrams, and flow models to track energy transformations from light or food to adenosine triphosphate (ATP). Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 2: Instruction includes losses to heat at each transformation step.

Clarification 3: Instruction includes examining historical developments that contributed to scientific understanding of cellular energy transformations. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.1.3 Identify energy transfer mechanisms in living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes energy transfer pathways: diffusion, osmosis, active transport, and electron transport chains.

Clarification 2: Instruction includes the role of enzymes in lowering activation energy and channeling energy flow in pathways.

Clarification 3: Instruction includes using models to represent biological energy-transfer pathways and energy flow in living systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EL.1.4 Interpret energy diagrams and ecosystem flow representations.

Benchmark Clarifications:

Clarification 1: Instruction includes reading and constructing energy bar charts for pathways and Sankey diagrams for ecosystems.

Clarification 2: Instruction includes trophic energy loss and ecological efficiency across food webs.

Clarification 3: Instruction includes marine food webs involving phytoplankton, zooplankton, macroalgae, invertebrates, fishes, marine mammals, decomposers, and detrital pathways.

Clarification 4: Instruction includes interpreting relationships among energy input, storage, transfer, and loss using graphical and quantitative representations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.2 Explain how cells capture, transform, and utilize energy through pathways, gradients, and enzymes to perform biological work.

SC.912.EL.2.1 Analyze energy changes associated with photosynthesis, cellular respiration, and biological pathways using provided data and energy relationships.

Benchmark Clarifications:

Clarification 1: Instruction includes energy yield estimates for respiration and photosynthesis with given constraints.

Clarification 2: Instruction includes interpreting quantitative relationships among energy input, energy storage, and energy yield using provided data, graphs, and tables. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.2.2 Calculate rates for energy transport and metabolism in living things.

Benchmark Clarifications:

Clarification 1: Instruction includes how living things move materials containing energy and carry out chemical processes that release or use energy to sustain life functions.

Clarification 2: Instruction includes that rates are calculated as (measured quantity)/time using provided data, equations, graphs, or tables.

Clarification 3: Instruction includes applying proportional reasoning, graph interpretation, and unit analysis to calculate rates. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.2.3 Explain how cells gain, use, and store energy during photosynthesis and cellular respiration.

Benchmark Clarifications:

Clarification 1: Instruction includes how cells capture energy from the environment such as light energy absorbed during photosynthesis and chemical energy obtained from food molecules during cellular respiration.

Clarification 2: Instruction includes how cells release and transfer energy to carry out life processes including growth, repair, movement, and maintaining homeostasis.

Clarification 3: Instruction includes how energy is stored in chemical bonds of molecules such as glucose and adenosine triphosphate (ATP) for later use.

Clarification 4: Instruction includes how photosynthesis stores energy in glucose and how cellular respiration releases that stored energy to make adenosine triphosphate (ATP).

Clarification 5: Instruction includes phytoplankton, macroalgae, seagrasses, and photosynthetic microorganisms as major contributors to primary productivity, oxygen production, and energy storage within marine ecosystems.

Clarification 6: Instruction excludes detailed molecular pathways and chemical equations.

Clarification 7: Instruction includes using system models to represent energy capture, storage, transfer, and release during photosynthesis and cellular respiration. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EL.3 Explain how heat transfer, thermoregulation, and energy budgets influence organism function, performance, survival, and ecological interactions.

SC.912.EL.3.1 Distinguish heat versus temperature in living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes the effects of body size and insulation on heat exchange and performance.

Clarification 2: Instruction includes the thermal budgets of living organisms.

Clarification 3: Instruction includes the differences in heat gain and heat loss mechanisms: radiation, convection, conduction, and evaporation.

Clarification 4: Instruction includes using thermal and particle models to explain heat transfer in organisms. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.3.2 Calculate energy exchange during thermoregulation within living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes the process by which living organisms maintain a stable internal body temperature despite changes in the external environment by gaining, losing, or redistributing thermal energy.

Clarification 2: Instruction includes the transfer of thermal energy between a living organism and its surroundings through mechanisms such as conduction, convection, radiation, and evaporation.

Clarification 3: Instruction includes internal energy changes due to metabolic activity.

Clarification 4: Instruction includes calculations based upon provided data, formulas, graphs, or tables to determine heat gained or lost, energy required to maintain body temperature or changes in internal temperature over time.

Clarification 5: Instruction includes relationships among salinity, dissolved oxygen, temperature, and physiological energy demands in marine organisms.

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Clarification 6: Instruction excludes memorizing specific physiological structures related to thermoregulation.

Clarification 7: Instruction includes applying mathematical relationships and interpreting graphs and data to evaluate thermoregulation and thermal energy exchange. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.3.3 Describe the adaptations that manage energy and temperature in living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes the trade-offs between saving energy and being active: endotherms and ectotherms.

Clarification 2: Instruction includes that living organisms control body temperature and save energy through processes such as countercurrent exchange, evaporative cooling, hibernation, torpor, and behavioral thermoregulation.

Clarification 3: Instruction includes physiological adaptations of marine organisms such as osmoregulation, buoyancy regulation, countercurrent exchange, oxygen storage, and thermal regulation.

SC.912.EL.3.4 Interpret graphs that show how living organisms grow and use energy over time.

Example: Given that energy budgets can change depending on the environment, explain why organisms grow, reproduce, or survive based upon food availability, temperature, and habitat type.

Benchmark Clarifications:

Clarification 1: Instruction includes that living organisms have a limited amount of energy that is divided for maintenance, growth, and reproduction.

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Clarification 2: Instruction includes cumulative energy graphs that show how energy use adds up over time and how energy is shared between maintenance, growth, and reproduction.

Clarification 3: Instruction includes the ecological implications of energy budgets across environments.

Clarification 4: Instruction includes interpreting graphs and quantitative representations of biological energy use. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.4 Explain how chemical reactions in living things use enzymes to capture and change energy and how scientists measure these energy changes in labs and real-world settings.

SC.912.EL.4.1 Explain enzyme-catalyzed energy transformations in living cells.

Benchmark Clarifications:

Clarification 1: Instruction includes activation energy diagrams, the effects of inhibitors, and environmental influences such as temperature and pH.

Clarification 2: Instruction includes coupling of endergonic and exergonic reactions via adenosine triphosphate (ATP) and redox carriers.

SC.912.EL.4.2 Apply calorimetry and spectroscopy to measure energy in biological systems.

Benchmark Clarifications:

Clarification 1: Instruction includes how calorimetry is used to measure energy in foods and photosynthetic heat signatures.

Clarification 2: Instruction includes how spectrophotometers or colorimeters measure enzyme activity and pigment absorption.

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Clarification 3: Instruction includes designing, conducting, and evaluating investigations involving calorimetry, spectroscopy, or colorimetry. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.4.3 Explain how the physical and chemical properties of water regulate energy changes in biological systems.

Benchmark Clarifications:

Clarification 1: Instruction includes how water absorbs and releases large amounts of energy during temperature changes and phase transitions to maintain stable internal temperatures in living things.

Clarification 2: Instruction includes how water's molecular structure and solvent properties support efficient energy transfer and influence the rate of chemical reactions essential for cellular processes.

Clarification 3: Instruction includes the role of water in regulating temperature, supporting marine productivity, transporting nutrients, and influencing biological processes within aquatic and marine ecosystems.

SC.912.EL.4.4 Connect enthalpy and energy transformations to biological processes in cells, living organisms, and ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes how changes in enthalpy drive energy transformations that power cellular processes such as metabolism, growth, and reproduction.

Clarification 2: Instruction includes how biological energy transformations contribute to ecosystem energy flow, matter cycling, and feedback between living systems, Earth systems, and climate.

Clarification 3: Instruction includes movement of carbon, nitrogen, phosphorus, and other nutrients among marine organisms, sediments, seawater, and the atmosphere.

Clarification 4: Instruction includes biological processes that transfer carbon from marine producers to deep-water and sediment reservoirs.

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Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of biological energetics, metabolism, and ecosystem energy flow. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.5 Explain how living systems use electrical and photonic energy and how membranes and transport processes move and transform energy for cellular work.

SC.912.EL.5.1 Explain how differences in electric charge across cell membranes store energy and assist cellular work.

Benchmark Clarifications:

Clarification 1: Instruction includes that cells store usable energy by maintaining differences in charged particles across membranes.

Clarification 2: Instruction includes a qualitative understanding that ion differences across membranes create electrochemical gradients that influence the direction and magnitude of electrical energy available to cells.

Clarification 3: Instruction includes that electrical differences across membranes assist cells with work such as signaling transport and adenosine triphosphate (ATP) production.

SC.912.EL.5.2 Compute power or energy use of living processes.

Benchmark Clarifications:

Clarification 1: Instruction includes approximate energy budgets for muscle work, ion pumping, and biosynthesis.

Clarification 2: Instruction includes environmental conditions, such as temperature and oxygen availability, on power output and efficiency.

Clarification 3: Instruction includes applying proportional reasoning and unit analysis to compute biological power output and energy use. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EL.5.3 Analyze how energy moves and is lost in cell systems that work like circuits.

Benchmark Clarifications:

Clarification 1: Instruction includes that cells release energy in steps during processes such as electron transport and that some energy moves through proton leaks and is released as heat rather than being stored.

Clarification 2: Instruction includes that living organisms balance energy efficiency and heat production resulting in trade-offs between making adenosine triphosphate (ATP) and generating thermal energy.

Clarification 3: Instruction includes using system models and energy-flow diagrams to explain energy transfer and dissipation in cellular pathways. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.5.4 Connect bioelectric and photonic energy to sensing and power in life.

Benchmark Clarifications:

Clarification 1: Instruction includes photoreception, bioluminescence, and bioelectric signaling.

Clarification 2: Instruction includes applying electrical and light energy concepts in biology to real-world systems including medical monitoring and ecological energy interactions.

Clarification 3: Instruction includes bioluminescence, photoreception, camouflage, communication, predation, and defense strategies within marine ecosystems.

Clarification 4: Instruction includes examining historical developments that contributed to scientific understanding of optics, vision, electrophysiology, and bioluminescence. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.6 Explain how organisms and ecosystems obtain, convert, store, and manage energy and how efficiency and constraints shape biological strategies.

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SC.912.EL.6.1 Compare energy sources and efficiencies in living systems.

Benchmark Clarifications:

Clarification 1: Instruction includes light versus chemical energy.

Clarification 2: Instruction includes aerobic versus anaerobic energy pathways.

Clarification 3: Instruction includes evaluating energy sources in ecosystems such as sunlight, food chains, and decomposers.

Clarification 4: Instruction includes energy yield, energy rate, and how conditions such as oxygen, light, nutrients, and temperature affect energy use.

Clarification 5: Instruction includes phytoplankton and macroalgae as primary producers, prey resources, oxygen producers, nutrient cyclers, habitat-forming organisms, and symbiotic partners.

Clarification 6: Instruction includes chemosynthetic organisms that obtain energy from inorganic compounds in environments where sunlight is unavailable.

SC.912.EL.6.2 Interpret efficiency in biological pathways and ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes the relative efficiency of biological energy pathways based on adenosine triphosphate (ATP) yield per substrate.

Clarification 2: Instruction includes that energy is lost as heat at every step of energy conversion consistent with the Law of Thermodynamics.

Clarification 3: Instruction includes the 10% Rule as a heuristic to describe trophic transfer efficiency and cumulative reduction of available energy across successive trophic levels in food chains and food webs.

SC.912.EL.6.3 Describe energy conversion pathways in living organisms and ecosystems.

Benchmark Clarifications:

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Clarification 1: Instruction includes using energy flow diagrams and Sankey charts to visualize living organisms and ecosystem energy flows.

Clarification 2: Instruction includes the conversion of food energy into adenosine triphosphate (ATP) resulting in movement, growth, and heat.

Clarification 3: Instruction includes the conversion of light energy into chemical energy resulting in plant biomass.

Clarification 4: Instruction includes energy moving through decomposer (detrital) pathways.

Clarification 5: Instruction includes marine food-web examples involving coral reefs, estuaries, mangrove ecosystems, seagrass communities, and open-ocean systems.

Clarification 6: Instruction includes using energy-flow models, food-web models, and Sankey diagrams to represent energy movement through biological systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.6.4 Compare biological energy storage and management.

Benchmark Clarifications:

Clarification 1: Instruction includes energy storage molecules such as glycogen, lipids, and starch.

Clarification 2: Instruction includes short versus long-term energy storage in living organisms.

Clarification 3: Instruction includes system level regulation of energy use such as hormonal control and feedbacks.

Clarification 4: Instruction includes survival strategies such as hibernation, torpor, brumation, and dormancy.

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SC.912.EL.7 Analyze how energy principles govern biological processes across molecular, cellular, living organism, and ecosystem levels; and evaluate how physical laws, efficiency limits, and the anthropogenic effects on energy flow, regulation, and sustainability in living systems.

SC.912.EL.7.1 Explain how energy and entropy influence spontaneity and equilibrium in biological systems.

Benchmark Clarifications:

Clarification 1: Instruction includes relationships among Gibbs Free Energy, enthalpy, entropy, and temperature as indicators of spontaneity in biological systems.

Clarification 2: Instruction includes explaining how spontaneity and equilibrium influence biochemical pathways, metabolic regulation, and cellular processes.

Clarification 3: Instruction includes interpreting mathematical relationships and graphical models describing spontaneity and equilibrium. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using energy diagrams and thermodynamic models to represent spontaneity and equilibrium. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.7.2 Analyze energy stored in electrochemical gradients and fields in living systems.

Benchmark Clarifications:

Clarification 1: Instruction includes how energy is stored in ion-concentration gradients, membrane potentials, and signaling energetics to perform work through diffusion, active transport, and adenosine triphosphate (ATP) synthesis.

Clarification 2: Instruction includes mitochondrial and chloroplast membranes, neuronal action potentials, muscle contractions, and secondary active transport.

Clarification 3: Instruction excludes mathematical calculations, formal equations, or quantitative modeling of membrane potentials, ion gradients, or electrical properties.

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Clarification 4: Instruction includes interpreting relationships among ion gradients, membrane potentials, and energy storage. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using membrane and electrochemical-gradient models to explain energy storage. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.7.3 Describe photon energy transfer and its role in biological energy conversion.

Benchmark Clarifications:

Clarification 1: Instruction includes relating photon energy to wavelength and frequency and explaining how absorbed photons excite electrons and initiate biological and chemical processes.

Clarification 2: Instruction includes relationships among light penetration, photosynthesis, ocean depth, water clarity, and marine primary productivity.

Clarification 3: Instruction includes applying relationships among wavelength, frequency, and photon energy and interpreting absorption and reflectance spectra. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes photosynthetic light reactions, pigment absorption spectra, photoreceptor function in vision, spectroscopy, remote sensing of vegetation, and applications used to evaluate biological energy capture and ecosystem productivity. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction excludes quantum mechanical derivations.

Clarification 6: Instruction includes examining historical developments that contributed to scientific understanding of light, photosynthesis, vision, spectroscopy, and remote sensing. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.EL.7.4 Explain how energy use and efficiency scale across levels of biological organization.

Benchmark Clarifications:

Clarification 1: Instruction includes how energy demand, metabolic rate, and efficiency vary with living organism size, surface area-to-volume ratios, and biological structure.

Clarification 2: Instruction includes connecting energy transformations across biological scales from molecular processes to living organism physiology and ecosystem energy flow.

Clarification 3: Instruction includes interpreting proportional relationships and biological scaling trends using provided data, graphs, and models. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.7.5 Explain how energy flows through ecosystems and how efficiency limits energy transfer between trophic levels.

Benchmark Clarifications:

Clarification 1: Instruction includes the transformation of solar energy into chemical energy by producers through photosynthesis and the transfer of that energy through consumers and decomposers within ecosystems.

Clarification 2: Instruction includes how energy is lost as heat at each trophic level due to metabolic processes resulting in a decrease of available free energy as energy moves through food chains and food webs.

Clarification 3: Instruction includes the concept of ecological efficiency and how limited energy transfer between trophic levels constrains food chain length and ecosystem structure.

Clarification 4: Instruction includes qualitative and quantitative representations of energy transfer between trophic levels, using energy pyramids, food chains, and food webs.

Clarification 5: Instruction excludes detailed biochemical pathway analysis and advanced thermodynamic calculations involving entropy or Gibbs Free Energy.

Clarification 6: Instruction includes the role of phytoplankton and macroalgae in supporting marine biodiversity, ecosystem productivity, and trophic energy transfer.

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Clarification 7: Instruction includes interpreting quantitative representations of trophic energy transfer. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 8: Instruction includes using energy pyramids, food-web models, and ecosystem energy-flow diagrams to represent ecological energy transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.EL.7.6 Evaluate the anthropogenic effect on energy flow and efficiency in ecosystems and predict ecological consequences.

Benchmark Clarifications:

Clarification 1: Instruction includes effects to primary productivity, trophic structure, and the availability of energy within ecosystems.

Clarification 2: Instruction includes how pollution affects energy transfer efficiency, metabolic costs, and living organism energy budgets across trophic levels.

Clarification 3: Instruction includes altered energy flow: trophic cascades, reduced biodiversity, changes in food web stability, and shifts in ecosystem services.

Clarification 4: Instruction includes evaluating how anthropogenic changes influence nutrient cycling, productivity, and energy flow within marine ecosystems.

Clarification 5: Instruction includes analyzing ecological datasets to evaluate anthropogenic effects on energy flow and ecosystem function. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

DRAFT

The Science of Matter

How matter is structured, how particles interact, and how substances are transformed through chemical and physical processes.

Grades 9-12

Proposed DRAFT Standards

SC.912.M.1 Explain how atomic structure, valence electrons, periodic trends, and chemical formulas determine the formation of ionic and covalent bonds, the structure and properties of molecules and compounds, and the breaking and forming of bonds during chemical reactions.

SC.912.M.1.1 Recall the structure of an atom.

Benchmark Clarifications:

Clarification 1: Instruction includes protons, neutrons, electrons, nucleus, electron cloud, atomic number, and mass number.

Clarification 2: Instruction includes using models to represent atomic structure. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.1.2 Explain how valence electrons determine an element's bonding behavior.

Benchmark Clarifications:

Clarification 1: Instruction includes that metals tend to lose valence electrons, while nonmetals tend to gain or share electrons.

SC.912.M.1.3 Differentiate between ionic bonding (electron transfer) and covalent bonding (electron sharing).

Benchmark Clarifications:

Clarification 1: Instruction includes using models to explain how each type of bond forms.

Clarification 2: Instruction includes using particle models and Lewis Electron-dot models to explain how ionic and covalent bonds form. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.1.4 Identify the number and types of atoms in a chemical formula.

Benchmark Clarifications:

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Clarification 1: Instruction includes subscripts, coefficients, element symbols, and determining the number and type of atoms represented in chemical formulas.

SC.912.M.1.5 Explain how chemical formulas represent the composition of molecules or ionic compounds.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting chemical formulas as representations of elemental composition and relative proportions of atoms in molecules and ionic compounds.

SC.912.M.1.6 Construct Lewis dot diagrams to show how valence electrons are rearranged or shared in ionic and covalent bonds.

Benchmark Clarifications:

Clarification 1: Instruction includes using Lewis Electron-dot models to explain how ionic and covalent bonds form. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.1.7 Describe how different types of chemical bonds influence physical properties of substances.

Benchmark Clarifications:

Clarification 1: Instruction includes properties such as melting point, conductivity, solubility, and hardness.

SC.912.M.1.8 Distinguish between molecules and compounds.

Benchmark Clarifications:

Clarification 1: Instruction includes how chemical bonds determine the structure of molecules and compounds.

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Clarification 2: Instruction includes that all compounds consist of two or more elements bonded together, but not all compounds are made of molecules.

SC.912.M.1.9 Describe how chemical reactions break and form bonds.

Benchmark Clarifications:

Clarification 1: Instruction includes that chemical reactions involve the breaking of existing chemical bonds and the formation of new ones resulting in new substances.

SC.912.M.1.10 Analyze periodic table patterns to predict element bonding.

Benchmark Clarifications:

Clarification 1: Instruction includes ionic or covalent bonds.

Clarification 2: Instruction includes metals versus nonmetals, groups, and valence electrons.

Clarification 3: Instruction includes analyzing patterns and relationships to predict element bonding. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.1.11 Identify alkanes, alkenes, alkynes, and aromatic hydrocarbons.

Benchmark Clarifications:

Clarification 1: Instruction includes relating structures to degrees of saturation and basic molecular formulas.

Clarification 2: Instruction includes identifying single, double, and triple carbon-carbon bonds and recognizing how bond type distinguishes alkanes, alkenes, and alkynes

Clarification 3: Instruction includes recognizing benzene rings and other aromatic structures as a distinct class of hydrocarbons characterized by delocalized electrons.

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Clarification 4: Instruction includes comparing structural characteristics of hydrocarbon classes and relating those characteristics to molecular composition and reactivity at an introductory level.

Clarification 5: Instruction includes recognizing patterns among molecular formulas, carbon number, and degree of saturation. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes using structural, condensed structural, and skeletal models to classify hydrocarbons and represent carbon-carbon bonding patterns. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.1.12 Recognize common functional groups.

Benchmark Clarifications:

Clarification 1: Instruction includes alcohol, aldehyde, ketone, carboxylic acid, ester, ether, amine, and alkyl halide.

Clarification 2: Instruction includes identifying functional groups in structural, condensed structural, and skeletal formulas.

Clarification 3: Instruction includes recognizing that functional groups influence the chemical and physical properties of organic compounds.

Clarification 4: Instruction includes comparing organic compounds based on the presence and arrangement of functional groups.

Clarification 5: Instruction includes identifying patterns among molecular structures, molecular formulas, and functional-group composition. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes using structural models, molecular representations, and symbolic formulas to identify and compare functional groups. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.M.1.13 Draw and name simple organic structures using introductory International Union of Pure and Applied Chemistry (IUPAC) rules and recognize structural versus geometric isomers.

Benchmark Clarifications:

Clarification 1: Instruction includes straight chains and select branched structures.

Clarification 2: Instruction includes determining the longest continuous carbon chain and applying introductory IUPAC naming conventions for hydrocarbons and selected functionalized compounds.

Clarification 3: Instruction includes drawing structural, condensed structural, and skeletal formulas for simple organic compounds.

Clarification 4: Instruction includes distinguishing structural isomers that differ in atom connectivity from geometric isomers that differ in spatial arrangement around double bonds.

Clarification 5: Instruction includes recognizing that compounds with the same molecular formula may have different structures and properties.

Clarification 6: Instruction includes applying spatial reasoning, pattern recognition, and symbolic relationships when naming compounds and identifying isomers. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 7: Instruction includes constructing and interpreting structural, condensed structural, skeletal, and isomer models to represent organic compounds. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2 Explain how particle-level structure and interactions, including atomic structure, isotopes, periodic trends, bonding, intermolecular forces, states of matter, gas behavior, solutions, physical and chemical changes, and nuclear phenomena determine the composition, properties, transformations, and applications of matter.SC.912.M.2.1 Classify matter by particle-level composition and properties.

Benchmark Clarifications:

Clarification 1: Instruction includes distinguishing elements, compounds, and mixtures at the particulate level.

Clarification 2: Instruction includes interpreting particle diagrams that represent homogeneous and heterogeneous mixtures. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.2 Describe the atomic structure of an element with the atomic number and mass number of the same element.

Benchmark Clarifications:

Clarification 1: Instruction includes determining the number of protons, neutrons, and electrons from the atomic number and mass number of an atom.

Clarification 2: Instruction includes relating atomic number to the identity of an element and mass number to the total number of protons and neutrons in the nucleus.

Clarification 3: Instruction includes representing atomic structure using atomic symbols and particle models. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.3 Explain the relationship of an isotope of an element with the average atomic mass of the same element.

Benchmark Clarifications:

Clarification 1: Instruction includes that isotopes of an element have the same number of protons but different numbers of neutrons.

Clarification 2: Instruction includes distinguishing mass number from average atomic mass.

Clarification 3: Instruction includes explaining that average atomic mass reflects the weighted average of naturally occurring isotopes of an element.

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Clarification 4: Instruction includes interpreting isotope abundance data and weighted-average relationships. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using isotope notation, atomic symbols, and isotope abundance representations to model isotope relationships. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.4 Explain periodic trends using electron configuration.

Benchmark Clarifications:

Clarification 1: Instruction includes describing trends in electronegativity, ionization energy, and atomic radius across periods and down groups.

Clarification 2: Instruction includes connecting valence electrons to chemical reactivity and periodicity.

SC.912.M.2.5 Describe metallic bonding.

Benchmark Clarifications:

Clarification 1: Instruction includes delocalized electrons (commonly referred to as the sea of electrons) and metallic lattice structure.

Clarification 2: Instruction includes properties explained by metallic bonding: conductivity, malleability, and luster.

SC.912.M.2.6 Compare ionic, covalent, and metallic bonding at the electron level.

SC.912.M.2.7 Relate polarity and intermolecular forces to boiling point and solubility.

Benchmark Clarifications:

Clarification 1: Instruction includes London dispersion forces, dipole-dipole interactions, hydrogen bonding, and ion-dipole interactions.

Clarification 2: Instruction includes relationships among intermolecular forces, boiling point, melting point, viscosity, and solubility.

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Clarification 3: Instruction includes using particle models to explain intermolecular attractions. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.8 Determine molecular polarity by adding bond dipoles as vectors based on Lewis structures and Valence Shell Electron Pair Repulsion (VSEPR) geometries and relate polarity to intermolecular forces and properties.

Benchmark Clarifications:

Clarification 1: Instruction includes arrow (vector) conventions, three-dimensional geometries (linear, trigonal planar, tetrahedral, trigonal pyramidal, bent), and symmetry cancellation.

Clarification 2: Instruction includes interpreting vector representations, spatial relationships, symmetry, and directional properties to determine molecular polarity from bond dipoles and molecular geometry. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.9 Analyze states of matter and phase changes.

Benchmark Clarifications:

Clarification 1: Instruction includes solid, liquid, gas, and plasma.

Clarification 2: Instruction includes melting, freezing, vaporization, boiling, evaporation, condensation, sublimation, and deposition.

Clarification 3: Instruction includes using particle-level and phase-change models to explain the characteristics of states of matter and transitions among phases. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.10 Interpret phase diagrams to identify phase regions, phase boundaries, the triple point, and the critical point.

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Benchmark Clarifications:

Clarification 1: Instruction includes identifying solid, liquid, and gas regions and the boundaries that separate them on a phase diagram.

Clarification 2: Instruction includes locating and interpreting the triple point and critical point and explaining what each represents.

Clarification 3: Instruction includes recognizing the difference between typical phase diagrams and water's unique negative solid-liquid slope.

Clarification 4: Instruction includes using phase diagrams and graphical models to represent relationships among temperature, pressure, and phase stability. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.11 Predict phase changes under changing temperature and pressure.

Benchmark Clarifications:

Clarification 1: Instruction includes using phase diagrams to determine the phase of a substance at given temperature and pressure conditions.

Clarification 2: Instruction includes predicting how a substance's phase will change when temperature or pressure increases or decreases.

Clarification 3: Instruction includes determining whether a phase change crosses a boundary and identifying the corresponding transition.

Clarification 4: Instruction includes using phase diagrams and particle models to predict phase behavior under changing temperature and pressure conditions. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.12 Apply gas laws to predict behavior under changing conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes using proportional and algebraic reasoning with pressure, volume, temperature, and moles.

Clarification 2: Instruction includes Boyle's Law, Charles's Law, Gay-Lussac's Law, Combined Gas Law, and the Ideal Gas Law.

Clarification 3: Instruction includes applying algebraic relationships, proportional reasoning, graph interpretation, and unit analysis to predict gas behavior under changing conditions. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.13 Calculate solution concentration and interpret solubility.

Benchmark Clarifications:

Clarification 1: Instruction includes molarity calculations.

Clarification 2: Instruction includes the effects of temperature, pressure, and intermolecular forces on solubility.

Clarification 3: Instruction includes salinity as a measure of dissolved substances in seawater and relationships among concentration, density, and marine environmental conditions.

Clarification 4: Instruction includes applying proportional reasoning, unit analysis, and quantitative relationships to calculate concentration and interpret solubility data. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.14 Distinguish physical changes from chemical changes.

Benchmark Clarifications:

Clarification 1: Instruction includes evidence for chemical reactions: energy change, gas, precipitate, and color change.

Clarification 2: Instruction includes modeling dissolution as a physical process unless a new substance forms.

SC.912.M.2.15 Model how nuclear reactions and radioactive decay alter the composition of matter.

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Benchmark Clarifications:

Clarification 1: Instruction includes alpha, beta, and gamma decay.

Clarification 2: Instruction includes fission and fusion.

Clarification 3: Instruction includes using half-life to quantify radioactive decay.

Clarification 4: Instruction includes using nuclear equations, decay series, isotope notation, and graphical representations to model nuclear changes and radioactive decay. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of radioactivity, nuclear structure, and nuclear transformations. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.2.16 Analyze Earth and space matter contexts that illustrate composition, structure, and change.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship between minerals, rocks, atmospheric composition, and particle-level structure.

SC.912.M.2.17 Evaluate the interactions of ionizing radiation with matter and explain how radiation type influences penetration, energy transfer, and biological effects.

Example: Compare the penetration of alpha, beta, and gamma radiation through various materials.

Example: Analyze radiation exposure risks in medical, industrial, and environmental settings.

Benchmark Clarifications:

Clarification 1: Instruction includes alpha, beta, gamma, neutron, and x-radiation.

Clarification2: Instruction includes ionization, excitation, and energy transfer.

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Clarification 3: Instruction includes factors affecting radiation penetration and attenuation.

Clarification 4: Instruction includes applications of shielding materials.

SC.912.M.2.18 Investigate methods used to detect, measure, and monitor radioactive materials and radiation exposure.

Example: Analyze environmental radiation measurements.

Example: Compare radiation dose rates from natural and human-made sources.

Benchmark Clarifications:

Clarification 1: Instruction includes Geiger-Müller detectors, scintillation detectors, dosimeters, and radiation surveys.

Clarification 2: Instruction includes radiation measurement units.

Clarification 3: Instruction includes interpreting radiation monitoring data.

SC.912.M.2.19 Model nuclear technologies used in medicine, industry, scientific research, and energy production.

Benchmark Clarifications:

Clarification 1: Instruction includes diagnostic imaging, radiation therapy, industrial tracers, and sterilization technologies.

Clarification 2: Instruction includes radioisotopes used in scientific investigations.

SC.912.M.3 Explain how the properties, strength, and behavior of acids and bases; equilibrium and solubility relationships; thermochemical and thermodynamic principles; and oxidation-reduction and electrochemical processes, including titrations, buffers, and galvanic cells, describe and predict reactions and changes in aqueous systems.

SC.912.M.3.1 Explain that strong acids and strong bases completely dissociate in water.

Benchmark Clarifications:

Clarification 1: Instruction includes how strong acids and strong bases differ from weak acids and weak bases.

Clarification 2: Instruction includes comparing complete dissociation of strong acids and bases with the partial dissociation of weak acids and bases.

Clarification 3: Instruction includes using particle-level models to represent acid and base dissociation in aqueous solutions. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.2 Calculate pH, pOH, [H^+], and [〖OH〗^-] for strong acids and strong bases.

Benchmark Clarifications:

Clarification 1: Instruction includes using logarithmic relationships and significant figures.

Clarification 2: Instruction includes converting among pH, pOH, hydrogen ion concentration, and hydroxide ion concentration.

Clarification 3: Instruction includes applying logarithmic relationships, algebraic reasoning, and quantitative analysis to describe acidity and basicity. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.3 Analyze how acid-base chemistry influences the pH of aquatic and marine systems and explain the consequences of pH changes on chemical and biological processes.

SC.912.M.3.4 Determine equilibrium concentrations for weak acids or weak bases.

Benchmark Clarifications:

Clarification 1: Instruction includes using equilibrium relationships and concentration tables to calculate equilibrium concentrations for weak acids and bases, including appropriate algebraic or approximation methods.

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Clarification 2: Instruction includes interpreting acid- and base-equilibrium constants to determine the degree of ionization and relate acid or base strength to equilibrium concentrations and pH.

Clarification 3: Instruction includes converting among hydrogen ion concentration, hydroxide ion concentration, pH, and pOH using appropriate acid-base relationships, significant figures, and logarithmic rules.

Clarification 4: Instruction includes using equilibrium tables, concentration relationships, and graphical representations to model weak acid and weak base equilibria. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes applying algebraic reasoning and equilibrium relationships to determine unknown concentrations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.5 Design buffer solutions at target pH.

Benchmark Clarifications:

Clarification 1: Instruction includes quantitative relationships among pH, conjugate acid-base pairs, and concentration.

Clarification 2: Instruction includes choosing appropriate conjugate pairs and estimating buffer capacity.

Clarification 3: Instruction includes evaluating how buffers resist changes in pH when small amounts of acid or base are added.

Clarification 4: Instruction includes carbonate buffering systems in seawater and factors influencing ocean pH.

Clarification 5: Instruction includes applying quantitative relationships among pH, acid-base conjugate pairs, and concentration. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 6: Instruction includes designing and evaluating buffer systems using chemical and graphical models. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.6 Interpret titration data to identify equivalence points and acid or base strength.

Benchmark Clarifications:

Clarification 1: Instruction includes using indicators or probes and sketching titration curves for strong-strong and weak-strong systems.

Clarification 2: Instruction excludes weak-weak titrations and polyprotic titration curves.

Clarification 3: Instruction includes interpreting titration curves, rates of pH change, and graphical relationships. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using titration curves and acid-base models to explain equivalence points and acid or base strength. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes collecting, analyzing, and interpreting titration data. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.7 Explain factors that affect the rate of chemical reactions using collision theory.

Benchmark Clarifications:

Clarification 1: Instruction includes concentration, temperature, surface area, and catalysts as factors that influence reaction rate.

Clarification 2: Instruction includes explaining reaction rates using particle collisions, collision frequency, and activation energy.

Clarification 3: Instruction includes interpreting reaction-rate data, graphs, and proportional relationships. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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Clarification 4: Instruction includes using collision models and activation-energy diagrams to explain reaction rates. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.8 Predict equilibrium shifts using Le Châtelier's Principle.

Benchmark Clarifications:

Clarification 1: Instruction includes concentration, temperature, and pressure changes.

Clarification 2: Instruction includes catalyst effects on rate only.

Clarification 3: Instruction includes interpreting graphical, quantitative, and equilibrium relationships associated with changing system conditions. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using equilibrium models to represent system responses to disturbances. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.9 Evaluate solubility and precipitation using equilibrium relationships.

Benchmark Clarifications:

Clarification 1: Instruction includes deciding precipitation and applying the common-ion effect.

Clarification 2: Instruction includes comparing ion concentrations with equilibrium relationships to determine dissolution, precipitation, or saturation.

Clarification 3: Instruction includes applying algebraic and quantitative relationships to evaluate solubility and precipitation. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using particle and equilibrium models to represent precipitation and dissolution processes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.M.3.10 Describe energy transfer in chemical reactions.

Benchmark Clarifications:

Clarification 1: Instruction includes endothermic and exothermic reactions and energy transfer between a system and its surroundings.

Clarification 2: Instruction includes energy changes associated with bond breaking and bond formation.

Clarification 3: Instruction includes interpreting energy diagrams and thermochemical representations. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.11 Calculate heat changes in chemical and physical processes.

Benchmark Clarifications:

Clarification 1: Instruction includes calculating heat transfer during temperature changes and phase changes.

Clarification 2: Instruction includes interpreting the sign and magnitude of thermal energy changes in chemical and physical systems.

Clarification 3: Instruction includes applying dimensional analysis, algebraic reasoning, and quantitative relationships to calculate heat changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes designing, conducting, and analyzing calorimetry investigations. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.12 Relate equilibrium constants to thermodynamics.

Benchmark Clarifications:

Clarification 1: Instruction includes relationships among free energy, equilibrium constants, and reaction favorability.

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Clarification 2: Instruction includes qualitative effects of temperature on equilibrium relationships and reaction favorability.

Clarification 3: Instruction includes interpreting equilibrium and thermodynamic relationships using mathematical and graphical representations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using thermodynamic and equilibrium models to explain reaction favorability and system behavior. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.13 Assign oxidation numbers and identify redox processes.

Benchmark Clarifications:

Clarification 1: Instruction includes standard oxidation-number rules.

Clarification 2: Instruction includes identifying electron transfer and agent roles from oxidation-state changes.

Clarification 3: Instruction includes using oxidation-number models and electron-transfer representations to identify oxidation and reduction processes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.3.14 Balance oxidation-reduction equations using the half-reaction method in acidic and basic media.

Benchmark Clarifications:

Clarification 1: Instruction includes balancing mass and charge via electrons, H_2O, H^+ (acidic), and OH^- (basic).

Clarification 2: Instruction includes applying algebraic reasoning and conservation principles to balance matter and charge. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes using half-reaction representations and redox models to explain electron transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.M.3.15 Analyze galvanic cells to identify anode, cathode, electron flow, salt bridge function, and calculate standard cell potential from half-cell data.

Benchmark Clarifications:

Clarification 1: Instruction includes cell notation, positive and negative sign conventions, and qualitative relationships among cell potential, reaction favorability, and equilibrium.

Clarification 2: Instruction includes applying quantitative relationships among cell potential, reaction favorability, and redox processes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 3: Instruction includes using galvanic-cell diagrams and electrochemical models to explain electron flow and cell operation. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes constructing, testing, and analyzing galvanic cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of electrochemistry, batteries, and galvanic cells. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.4 Apply the mole concept, balanced chemical equations, and stoichiometric relationships to convert among particles, moles, mass, and gas volume; determine limiting reactants, yields, and composition; and compute empirical and molecular formulas from data.

SC.912.M.4.1 Calculate the mass, moles, or number of particles of a substance using Avogadro’s number and molar mass in dimensional-analysis conversions.

Benchmark Clarifications:

Clarification 1: Instruction includes using molar mass and Avogadro's number to convert among mass, moles, and number of particles through dimensional analysis.

Clarification 2: Instruction includes calculating molar mass from formulas and reporting with appropriate significant figures and units.

Clarification 3: Instruction includes recognizing the mole as a counting unit and distinguishing representative particle types: atoms, molecules, formula units, and ions.

Clarification 4: Instruction includes applying dimensional analysis, proportional relationships, scientific notation, and unit conversions to determine relationships among mass, moles, and particles. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using particulate models and symbolic representations to illustrate relationships among atoms, molecules, formula units, ions, and moles. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.4.2 Balance chemical equations to calculate reactant or product quantities in moles, mass, or gas volume under specified conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes balancing chemical equations by adjusting coefficients to conserve atoms of each element.

Clarification 2: Instruction includes using balanced equations to establish molar ratios as the basis for stoichiometric calculations.

Clarification 3: Instruction includes identifying and writing states of matter and coefficients correctly.

Clarification 4: Instruction includes applying conservation relationships, proportional reasoning, and molar ratios when solving stoichiometric problems. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using particle models and balanced-equation representations to explain conservation of matter during chemical reactions. Refer to

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Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.4.3 Perform mole-mole, mass-mass, and volume (gas) stoichiometry calculations.

Benchmark Clarifications:

Clarification 1: Instruction includes using mole ratios from balanced equations to convert between moles, mass, and gas volume under stated conditions.

Clarification 2: Instruction includes gas-volume stoichiometry using standard molar-volume relationships and gas-law relationships when conditions vary.

Clarification 3: Instruction includes dimensional analysis and proper significant figures with attention to given conditions (temperature and pressure).

Clarification 4: Instruction includes applying dimensional analysis, algebraic reasoning, proportional relationships, and unit analysis in stoichiometric calculations. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using symbolic, particulate, and graphical representations to model quantitative relationships among reactants and products. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.4.4 Identify the limiting reactant in a reaction and compute theoretical yield, percent yield, and percent composition from quantitative data.

Benchmark Clarifications:

Clarification 1: Instruction includes identifying the limiting reactant by comparing theoretical product amounts from each reactant.

Clarification 2: Instruction includes calculating theoretical yield, actual yield, and percent yield.

Clarification 3: Instruction includes calculating percent composition from formulas or data and using it within composition analysis problems.

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Clarification 4: Instruction includes applying quantitative relationships, proportional reasoning, and percentage calculations when determining limiting reactants, yields, and composition. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes analyzing experimental yield data and comparing theoretical and actual results. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes using reaction models and particulate representations to explain limiting-reactant relationships and product formation. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.M.4.5 Analyze the composition or experimental data to calculate empirical formulas and determine molecular formulas when molar mass is provided.

Benchmark Clarifications:

Clarification 1: Instruction includes determining empirical formulas from percent composition or mass data by converting to moles and applying whole-number ratios.

Clarification 2: Instruction includes determining molecular formulas from empirical formula and molar mass.

Clarification 3: Instruction includes handling combustion analysis data at an introductory level and reporting formulas in proper conventional order.

Clarification 4: Instruction includes applying proportional reasoning, mole relationships, and quantitative analysis of composition data to determine empirical and molecular formulas. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes interpreting composition data and combustion-analysis data to construct chemical formula representations. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes analyzing experimental composition data and evaluating sources of uncertainty in calculated formulas. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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The Science of Force and Motion

How forces cause motion and interactions, how motion is described and predicted, and how fundamental force laws govern behavior from particles to planetary systems.

Grades 9-12

SC.912.FM.1 Explain how motion is described and predicted using speed, velocity, acceleration, and force; and apply Newton's Laws to describe how objects move in real-world situations.

SC.912.FM.1.1 Describe speed, velocity, and acceleration qualitatively in real-world contexts.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting distance and time graphs.

Clarification 2: Instruction includes interpreting speed, velocity, and time graphs (shape and slope).

Clarification 3: Instruction includes increasing speed, decreasing speed, and changing direction.

Clarification 4: Instruction includes interpreting graphical relationships among distance, displacement, velocity, acceleration, and time. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.1.2 Describe balanced forces in real-world contexts.

Benchmark Clarifications:

Clarification 1: Instruction includes qualitative free-body arrows for gravity, normal, friction, tension, and applied forces.

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Clarification 2: Instruction includes that when net force is equal to zero it is referred to as equilibrium.

Clarification 3: Instruction includes that when net force is not equal to zero it indicates a change in motion has occurred.

Clarification 4: Instruction includes using free-body diagrams and force models to represent balanced and unbalanced forces. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.1.3 Describe Newton's First Law of Motion as the principle of inertia.

Benchmark Clarifications:

Clarification 1: Instruction includes balanced and unbalanced forces.

Clarification 2: Instruction includes examining historical developments that contributed to scientific understanding of inertia and motion. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.1.4 Describe Newton's Second Law of Motion as the relationship between force, mass, and acceleration.

Benchmark Clarifications:

Clarification 1: Instruction includes that greater forces cause greater acceleration, and greater mass requires more force to accelerate.

Clarification 2: Instruction includes that acceleration happens when forces are unbalanced.

Clarification 3: Instruction includes interpreting proportional relationships among force, mass, and acceleration. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.1.5 Describe Newton's Third Law of Motion as forces that always come in equal and opposite pairs.

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Benchmark Clarifications:

Clarification 1: Instruction includes that when two objects interact, they push or pull on each other with equal force in opposite directions.

Clarification 2: Instruction includes force pairs acting on different objects.

Clarification 3: Instruction includes using interaction diagrams, free-body diagrams and force-pair models to represent Newton's Third Law. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2 Explain how motion is represented, analyzed, and predicted using kinematic relationships, vector components, motion graphs, and Newtonian concepts of force and acceleration in one and two dimensions.

SC.912.FM.2.1 Select the appropriate kinematic equation to describe motion based upon known information.

Benchmark Clarifications:

Clarification 1: Instruction includes the four kinematic equations: displacement, time, velocity, and acceleration.

Clarification 2: Instruction includes identifying which variables are known and choosing the appropriate equation for the situation based on what is given and what is missing.

Clarification 3: Instruction includes that kinematic equations apply only when acceleration is constant.

Clarification 4: Instruction includes using sign conventions to indicate positive or negative direction.

Clarification 5: Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.2 Evaluate how velocity changes when an object speeds up or slows down at a steady rate.

Benchmark Clarifications:

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Clarification 1: Instruction includes the relationship among initial velocity, final velocity, acceleration, and time during motion with constant acceleration.

Clarification 2: Instruction includes showing direction with positive and negative sign conventions and using appropriate units for velocity, acceleration, and time.

Clarification 3: Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.3 Determine how far an object moves when it starts with a velocity and accelerates steadily.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship among position, displacement, initial velocity, acceleration, and time during motion with constant acceleration.

Clarification 2: Instruction includes the difference between the change in position with direction (displacement) and how much ground was covered (distance).

Clarification 3: Instruction includes applying algebraic reasoning and quantitative relationships among position, velocity, acceleration, displacement, and time. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.4 Determine displacement when time is not given by using the no time kinematic equation.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship among velocity, acceleration, and displacement when time is not provided.

Clarification 2: Instruction includes using this equation when time is not provided or is hard to measure.

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Clarification 3: Instruction includes applying algebraic reasoning and quantitative relationships among velocity, acceleration, and displacement. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.5 Calculate displacement during constant acceleration by using average velocity and time.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship among displacement, average velocity, and time during motion with constant acceleration.

Clarification 2: Instruction includes how changing average velocity or time affects displacement.

Clarification 3: Instruction includes applying proportional reasoning and quantitative relationships among displacement, average velocity, and time. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.6 Explain two-dimensional projectile motion by resolving initial velocity into horizontal and vertical parts.

Benchmark Clarifications:

Clarification 1: Instruction includes constant horizontal velocity and constant vertical acceleration with no air resistance.

Clarification 2: Instruction includes using the vertical part of the motion to find how long the object is in the air and then combining the horizontal and vertical components to determine the total range and overall path.

Clarification 3: Instruction includes applying vector relationships, graphical analysis, and proportional reasoning to analyze projectile motion in real-world contexts. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using motion diagrams and vector models to represent two-dimensional motion. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.FM.2.7 Interpret motion graphs and relate slope and area to physical quantities.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting the slope of a position-time graph as velocity.

Clarification 2: Instruction includes interpreting the slope of a velocity-time graph as acceleration. Clarification 3: Instruction includes interpreting the area under a velocity-time graph as displacement.

Clarification 4: Instruction includes interpreting slope, area, rates of change, and graphical relationships among motion variables. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.8 Draw and analyze free-body diagrams for objects in one- and two-dimensional systems.

Benchmark Clarifications:

Clarification 1: Instruction includes identifying common forces: weight (gravity), normal force, tension, friction, and applied forces from pushes or pulls.

Clarification 2: Instruction includes drawing all the forces acting on an object, breaking angled forces into parts, and combining them to determine how the object will move. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.9 Determine the acceleration of an object of given mass from the net force acting on it.

Benchmark Clarifications:

Clarification 1: Instruction includes solving for unknowns in straight-line (linear) and inclined-planed systems with friction.

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Clarification 2: Instruction includes that acceleration and force can be positive or negative depending on the direction.

Clarification 3: Instruction includes appropriate units for force, mass, and acceleration.

Clarification 4: Instruction includes connecting each algebraic step to what the force is doing and why the object moves the way it does. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using free-body diagrams, force-vector models, and system models to represent forces acting on an object and determine the resulting acceleration. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.10 Explain Newton's Third Law when force pairs are interacting.

Benchmark Clarifications:

Clarification 1: Instruction includes that pairs act on different objects and are equal in magnitude and opposite in direction.

Clarification 2: Instruction includes mapping the pair across interaction types: contact, tension, reaction, and propulsion.

Clarification 3: Instruction includes using interaction diagrams and force-pair models to explain equal and opposite forces acting on different objects. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.11 Calculate static friction and determine when an object is about to start moving.

Benchmark Clarifications:

Clarification 1: Instruction includes that static friction varies up to a maximum value that prevents motion.

Clarification 2: Instruction includes determining when the applied force reaches the maximum static friction and impending motion occurs.

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Clarification 3: Instruction includes that the normal force affects the maximum possible static friction.

Clarification 4: Instruction includes applying proportional relationships among the coefficient of static friction, normal force, and maximum static friction to determine when motion will begin. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using free-body diagrams and force models to represent static friction, normal force, and impending motion in physical systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.12 Calculate kinetic friction when an object is sliding.

Benchmark Clarifications:

Clarification 1: Instruction includes that kinetic friction depends on the interaction between surfaces and the normal force during motion. Clarification 2: Instruction includes that kinetic friction is typically less than maximum static friction.

Clarification 3: Instruction includes the normal force and using it to find friction when an object is already moving.

Clarification 4: Instruction includes applying proportional relationships among the coefficient of kinetic friction, normal force, and kinetic friction to determine frictional forces during motion. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes using free-body diagrams and force models to represent kinetic friction and analyze motion in sliding systems. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.13 Calculate the centripetal acceleration for an object moving in a circular motion.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship among speed, radius, and centripetal acceleration during circular motion.

Clarification 2: Instruction includes how time for one rotation (period) and rotations per second (frequency) relate to circular motion at a qualitative level.

Clarification 3: Instruction includes interpreting mathematical relationships among speed, radius, period, frequency, and centripetal acceleration. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.14 Identify the force that acts as the centripetal force in different situations.

Benchmark Clarifications:

Clarification 1: Instruction includes that the centripetal force can come from normal force, tension, friction, or gravity depending on the situation.

Clarification 2: Instruction includes using real-world examples to identify the actual force or forces pulling the object toward the center.

Clarification 3: Instruction includes using free-body diagrams, force-vector representations, and circular-motion models to identify the force acting toward the center of a circular path and explain how that force produces centripetal acceleration. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.15 Calculate and interpret the work done by a constant force.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship among force, displacement, direction, and work.

Clarification 2: Instruction includes that work is positive when the force helps the motion and negative when the force opposes the motion based on the angle between the force and the direction of movement.

Clarification 3: Instruction includes applying algebraic relationships, unit analysis, and proportional reasoning to calculate work and interpret the effects of force, displacement,

and direction. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using free-body diagrams, force vectors, and energy-transfer representations to explain work done by forces acting on a system. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.16 Use the work-energy theorem to determine how an object's kinetic energy changes.

Benchmark Clarifications:

Clarification 1: Instruction includes that net work changes an object's kinetic energy.

Clarification 2: Instruction includes interpreting force-distance graphs to determine energy transfer and changes in kinetic energy.

Clarification 3: Instruction includes interpreting graphical representations and quantitative relationships among work, force, displacement, and kinetic energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using energy bar charts, energy-flow diagrams, and graphical models to represent relationships between work and changes in kinetic energy. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes designing, conducting, and analyzing investigations involving work, force, motion, and kinetic energy changes. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.17 Apply conservation of mechanical energy when non-conservative forces are not significant.

Benchmark Clarifications:

Clarification 1: Instruction includes that total mechanical energy remains constant when non-conservative forces are negligible.

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Clarification 2: Instruction includes selecting reference levels for potential energy and analyzing transformations among kinetic, gravitational, and elastic energy.

Clarification 3: Instruction includes applying quantitative relationships among kinetic energy, gravitational potential energy, elastic potential energy, and total mechanical energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using energy bar charts, energy-flow diagrams, and system models to represent transformations between kinetic and potential energy. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes designing, conducting, and evaluating investigations involving conservation of mechanical energy and transformations between kinetic and potential energy. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.2.18 Describe how non-conservative forces, such as friction or drag, change an object's mechanical energy.

Benchmark Clarifications:

Clarification 1: Instruction includes that non-conservative forces transfer energy from mechanical forms into thermal or other forms of energy.

Clarification 2: Instruction includes that non-conservative forces convert some mechanical energy into thermal or internal energy, which reduces the amount of mechanical energy the object keeps.

Clarification 3: Instruction includes interpreting quantitative relationships among mechanical energy, work, friction, drag, and thermal energy changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using energy-flow diagrams, system models, and graphical representations to explain how non-conservative forces transfer energy into thermal or internal energy. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.FM.3 Explain how particle-level motion and interactions produce observable properties of gases, liquids, and solids and how these interactions influence pressure, buoyancy, viscosity, surface tension, fluid motion, and phase behavior.

SC.912.FM.3.1 Relate gas pressure to how often and how hard particles collide with a surface.

Benchmark Clarifications:

Clarification 1: Instruction includes that pressure depends on the force exerted over an area and relating this concept to particle collisions with container surfaces.

Clarification 2: Instruction includes how increases in temperature increase particle motion and collision frequency, resulting in changes in pressure.

Clarification 3: Instruction includes interpreting relationships among pressure, force, area, temperature, and particle motion. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using particle models and graphical representations to explain pressure and particle collisions. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes designing and analyzing investigations involving pressure, temperature, or volume relationships in gases. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.3.2 Explain how intermolecular forces affect viscosity, surface tension, and phase changes.

Benchmark Clarifications:

Clarification 1: Instruction includes particle-level representations showing how intermolecular attractions influence the motion of particles.

Clarification 2: Instruction includes predicting viscosity, surface tension, droplet formation, and phase behavior from the strength of intermolecular forces.

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Clarification 3: Instruction includes comparing qualitative and quantitative trends among intermolecular force strength and observable properties. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using particle models and interaction models to explain viscosity, surface tension, and phase changes. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.3.3 Explain buoyancy and fluid motion using pressure differences within fluids.

Benchmark Clarifications:

Clarification 1: Instruction includes that pressure in fluids varies with depth and can create net upward forces.

Clarification 2: Instruction includes floating, sinking, neutral buoyancy, and displaced fluid.

Clarification 3: Instruction includes interpreting relationships among pressure, depth, density, and buoyant force. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using force diagrams, fluid models, and particle representations to explain buoyancy and fluid behavior. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes conducting investigations involving fluid density, buoyancy, and displacement. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.3.4 Analyze how fluid flow is influenced by pressure differences and conservation principles.

Benchmark Clarifications:

Clarification 1: Instruction includes qualitative relationships among fluid speed, pressure, and flow.

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Clarification 2: Instruction includes applications such as airfoils, ventilation systems, blood flow, and moving fluids.

Clarification 3: Instruction includes interpreting graphical and quantitative representations of fluid flow and pressure changes. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using fluid-flow models and system models to explain relationships among pressure, flow, and motion. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4 Explain how vector analysis, potential energy relationships, oscillatory motion, conservation principles, and fundamental force laws describe and predict physical behavior in one- and two-dimensional systems, including gravitational, electric, and magnetic interactions.

SC.912.FM.4.1 Analyze motion and forces by breaking vectors into components and comparing different reference frames.

Benchmark Clarifications:

Clarification 1: Instruction includes adding and subtracting vectors and splitting them into horizontal and vertical components for two-dimensional motion.

Clarification 2: Instruction includes that motion can look different depending on the observer's frame of reference.

Clarification 3: Instruction includes applying vector addition, subtraction, spatial reasoning, and trigonometric relationships to analyze motion and forces in one- and two-dimensional systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using vector diagrams, coordinate systems, and reference-frame models to represent motion and forces. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

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SC.912.FM.4.2 Use potential energy graphs to infer how forces act on an object.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting how changes in potential energy relate to the magnitude and direction of forces.

Clarification 2: Instruction includes stable and unstable points on a potential energy curve and describing small oscillations.

Clarification 3: Instruction includes interpreting slope, equilibrium positions, and graphical relationships among force, position, and potential energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using potential-energy diagrams and system models to explain force interactions and motion. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4.3 Describe how simple harmonic motion works in mass–spring and pendulum systems.

Benchmark Clarifications:

Clarification 1: Instruction includes explaining how position, velocity, and acceleration change during oscillations and how energy shifts between kinetic and potential forms.

Clarification 2: Instruction includes understanding that pendulum equations work best for small angles.

Clarification 3: Instruction includes interpreting graphical and proportional relationships among displacement, velocity, acceleration, period, frequency, and energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using oscillation models, motion graphs, and energy-transfer models to represent simple harmonic motion. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes designing, conducting, and analyzing investigations involving pendulum motion, spring oscillations, and factors that affect period and

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frequency. Refer to Laboratory Practices Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 6: Instruction includes examining historical developments that contributed to scientific understanding of pendulums, oscillations, and periodic motion. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4.4 Apply Coulomb's law and electric fields to describe forces between charges.

Benchmark Clarifications:

Clarification 1: Instruction includes describing how electric force depends on charge and distance and determining force direction using electric field representations.

Clarification 2: Instruction includes describing how electric fields influence charged objects and how multiple fields combine qualitatively through superposition.

Clarification 3: Instruction includes interpreting mathematical relationships among charge, distance, electric field strength, and electric force. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using electric-field diagrams, vector representations, and field models to explain interactions among charged objects. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of electric charge, electric fields, and electrostatic forces. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4.5 Extend gravitational potential energy to situations far from Earth's surface.

Benchmark Clarifications:

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Clarification 1: Instruction includes describing how gravitational potential energy depends on mass and distance in space systems.

Clarification 2: Instruction includes explaining qualitatively how this relates to orbiting or escaping a planet, without doing orbital mechanics calculations.

Clarification 3: Instruction includes interpreting mathematical relationships among mass, distance, and gravitational potential energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using gravitational-system models and energy representations to explain orbital motion and escape conditions. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of gravitation, orbital motion, and celestial mechanics. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4.6 Apply momentum conservation in two-dimensional collisions and explosion scenarios.

Benchmark Clarifications:

Clarification 1: Instruction includes using vector components and diagrams to track momentum in the x and y directions.

Clarification 2: Instruction includes describing center of mass motion qualitatively.

Clarification 3: Instruction includes applying vector relationships and conservation principles to analyze momentum before and after interactions. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using vector diagrams, collision models, and center-of-mass representations to explain momentum conservation. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4.7 Describe the relationship among magnetic forces, moving charges and electric currents.

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Benchmark Clarifications:

Clarification 1: Instruction includes describing how magnetic forces depend on magnetic field strength, charge, velocity, and direction.

Clarification 2: Instruction includes understanding how magnetic forces act on current-carrying wires.

Clarification 3: Instruction includes interpreting relationships among magnetic field strength, charge, current, velocity, and magnetic force. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using magnetic-field diagrams, vector representations, and field models to explain magnetic interactions. Refer to Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 5: Instruction includes examining historical developments that contributed to scientific understanding of magnetism, electromagnetism, and magnetic fields. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

SC.912.FM.4.8 Connect potential energy curves to how chemical bonds form and break.

Benchmark Clarifications:

Clarification 1: Instruction includes reading well depth on a potential curve to infer bond strength and identifying equilibrium bond length.

Clarification 2: Instruction includes explaining that breaking bonds absorbs energy and forming bonds releases energy, shaping net reaction enthalpy.

Clarification 3: Instruction includes interpreting graphical relationships among particle separation, potential energy, bond strength, and equilibrium position. Refer to Mathematics Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

Clarification 4: Instruction includes using potential-energy diagrams, particle models, and bond representations to explain chemical bonding and bond dissociation. Refer to

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Modeling Skills Supporting Mastery of 9-12 Energy, Matter, and Force and Motion Benchmarks.

The Science of Planet Earth

How Earth's systems interact, change over time, and are studied through energy flow, matter cycling, deep time, hazards and changing planetary conditions.

Grades 9-12

SC.912.PE.1 Analyze how Earth systems interact to transfer energy and recycle matter to shape Earth's surface and regulate long-term planetary stability.

SC.912.PE.1.1 Analyze how internal Earth processes transfer energy and move matter within the planet to build and reshape Earth's surface.

Benchmark Clarifications:

Clarification 1: Instruction includes the internal sources of energy such as residual heat from Earth's formation and heat produced by radioactive decay, and how thermal energy is transferred within Earth's interior through mantle convection.

Clarification 2: Instruction includes processes such as plate tectonics, volcanism, metamorphism, crustal deformation, and mountain building as mechanisms that transfer energy and redistribute matter within Earth.

Clarification 3: Instruction includes analyzing relationships among temperature, density, depth, and material movement within Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using conceptual models, mantle convection models, and systems models to represent internal energy transfer and movement of Earth materials. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing evidence from observations, maps, seismic data, and simulations used to investigate internal Earth processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 6: Instruction includes examining historical developments related to Earth's internal structure, mantle convection, continental drift, and plate tectonic theory. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.1.2 Demonstrate how external Earth processes transfer energy and recycle matter at Earth's surface.

Benchmark Clarifications:

Clarification 1: Instruction includes that solar energy is the primary driver of atmospheric circulation, weather, and the hydrologic cycle.

Clarification 2: Instruction includes gravity as a force that drives erosion, mass wasting, sediment transport, and deposition.

Clarification 3: Instruction includes surface processes such as weathering, erosion, deposition, and soil formation and the movement and recycling of matter by water, wind, ice, and waves.

Clarification 4: Instruction includes using systems models to represent the movement of energy and matter through Earth's surface processes. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing evidence from observations, maps, field investigations, and satellite imagery used to investigate surface processes and changes to Earth's surface. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.1.3 Analyze how internal and external Earth processes interact to form and modify landforms and Earth's surface features.

Benchmark Clarifications:

Clarification 1: Instruction includes landforms such as mountains, valleys, plateaus, plains, deltas, and ocean basins.

Clarification 2: Instruction includes constructive processes that build landforms and destructive processes that wear down landforms.

Clarification 3: Instruction includes interactions among tectonic uplift, volcanism, weathering, erosion, and deposition that contribute to landform development.

Clarification 4: Instruction includes using topographic maps, cross sections, and spatial data to analyze relationships between Earth processes and landforms. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using models to represent interactions among internal and external Earth processes that form and modify landforms. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.1.4 Evaluate how Earth systems regulate the cycling of matter and the flow of energy to maintain dynamic equilibrium over time.

Benchmark Clarifications:

Clarification 1: Instruction includes the conservation of matter within Earth systems through cycles such as the rock cycle, hydrologic cycle, and biogeochemical cycles.

Clarification 2: Instruction includes that energy flows through Earth systems and is transformed rather than recycled.

Clarification 3: Instruction includes dynamic equilibrium as a condition in which ongoing changes occur while overall system stability is maintained.

Clarification 4: Instruction includes analyzing matter cycling, energy flow, and feedback relationships within Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using systems models to represent energy flow, matter cycling, inputs, outputs, and interactions among Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.1.5 Assess the impacts of natural and anthropogenic disruptions on Earth system processes.

Benchmark Clarifications:

Clarification 1: Instruction includes natural disruptions such as hurricanes, earthquakes, volcanic eruptions, floods, tsunamis, tornadoes, and landslides.

Clarification 2: Instruction includes anthropogenic disruptions such as land-use change, resource extraction, energy production, and urbanization.

Clarification 3: Instruction includes that disruptions can have short-term and long-term effects on the transfer of energy, cycling of matter, and interactions among Earth systems.

Clarification 4: Instruction includes analyzing patterns, trends, and evidence associated with disruptions to Earth system processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes examining historical events that contributed to scientific understanding of natural hazards, environmental change, and Earth system responses. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.2 Analyze the structure and composition of Earth by distinguishing between chemical and physical layers and relating material properties to density, rigidity, and behavior.

SC.912.PE.2.1 Describe and distinguish how Earth is structured into chemical layers based upon composition and density.

Benchmark Clarifications:

Clarification 1: Instruction includes the chemical layers of Earth: crust, mantle, and core.

Clarification 2: Instruction includes differences between continental and oceanic crust in composition, thickness, and density.

Clarification 3: Instruction includes that the mantle is composed primarily of silicate material rich in magnesium and iron.

Clarification 4: Instruction includes that the core is comprised primarily of iron and nickel with distinctions between the outer and inner core.

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Clarification 5: Instruction includes using models to represent Earth's chemical layers and differences in composition, density, and thickness among layers. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.2.2 Differentiate how Earth is structured into physical layers based upon mechanical properties.

Benchmark Clarifications:

Clarification 1: Instruction includes physical layers such as lithosphere, asthenosphere, mesosphere (lower mantle), outer core, and inner core.

Clarification 2: Instruction includes factors that influence material behavior: rigidity, temperature, and pressure.

Clarification 3: Instruction includes using models to distinguish Earth's physical layers based on material behavior and mechanical properties. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.2.3 Analyze how density, temperature, and pressure influence the behavior of Earth’s materials.

Example: Analyze how solid Earth materials can bend and flow rather than break when exposed to high temperature and pressure by examining models, images, or simulations of plastic deformation.

Example: Describe how differences in density, temperature, and material behavior drive mantle convection and enable tectonic plate movement through cause-and-effect reasoning using diagrams or simulations.

Benchmark Clarifications:

Clarification 1: Instruction includes density differences as a result of composition and pressure conditions.

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Clarification 2: Instruction includes how increasing temperature and pressure with depth affect rock strength and deformation.

Clarification 3: Instruction includes analyzing relationships among density, temperature, pressure, and material behavior within Earth's interior. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using models to represent how density, temperature, and pressure influence the behavior and movement of Earth materials. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing observations, simulations, and experimental models used to investigate density-driven movement and material behavior within Earth. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.2.4 Evaluate how Earth’s internal structure influences large-scale Earth system behavior and surface features.

Benchmark Clarifications:

Clarification 1: Instruction includes how the asthenosphere enables plate tectonic movement of the lithosphere.

Clarification 2: Instruction includes how convection within the mantle transfers heat and drives internal Earth processes.

Clarification 3: Instruction includes how the liquid outer core contributes to the generation of Earth’s magnetic field.

Clarification 4: Instruction includes the connection between Earth’s layered structure and earthquakes, volcanism, and mountain building.

Clarification 5: Instruction includes using models to represent relationships among Earth's internal structure, energy transfer, plate movement, magnetic field generation, and surface features. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to Earth's internal structure, seismic-wave evidence, mantle convection, and magnetic field

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generation. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.3 Analyze how weathering, erosion, deposition, compaction, and cementation shape Earth's surfaces and contribute to soil formation and landscape change.

SC.912.PE.3.1 Describe and differentiate how weathering breaks down rocks and minerals and initiates a change on Earth's surface.

Example: Examine real-world images of weathered rocks and explain how physical, chemical, and biological weathering changed rock materials without transporting them to distinguish weathering from erosion.

Benchmark Clarifications:

Clarification 1: Instruction includes physical weathering processes such as freeze-thaw, abrasion, and root wedging.

Clarification 2: Instruction includes chemical weathering processes such as oxidation, hydrolysis, and dissolution.

Clarification 3: Instruction includes biological weathering caused by plants, animals, and microorganisms.

Clarification 4: Instruction includes using observations, images, and other evidence to distinguish weathering from erosion and identify physical, chemical, and biological weathering processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.3.2 Analyze how erosion transports weathered materials and reshapes Earth's surface.

Benchmark Clarifications:

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Clarification 1: Instruction includes erosion by water, wind, ice, waves, and gravity.

Clarification 2: Instruction includes the role of slope, water flow, wind speed, and ice movement in erosion rates.

Clarification 3: Instruction includes landforms created or modified by erosion such as valleys, canyons, caves, and coastlines.

Clarification 4: Instruction includes analyzing relationships among slope, water flow, wind speed, ice movement, and erosion rates. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using models to represent erosion processes and changes to Earth's surface caused by moving materials. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.3.3 Explain and sequence how deposition, compaction, and cementation recycle sediments and form sedimentary rocks.

Benchmark Clarifications:

Clarification 1: Instruction includes deposition as the settling of transported sediments when energy decreases.

Clarification 2: Instruction includes compaction as the process of sediments being pressed together by overlying layers.

Clarification 3: Instruction includes cementation as the binding of sediments by minerals precipitated from water.

Clarification 4: Instruction includes that these processes contribute to sedimentary rock formation and surface stability.

Clarification 5: Instruction includes using models to represent the sequence of deposition, compaction, and cementation and their role in sedimentary rock formation. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.3.4 Evaluate how Earth’s surface processes contribute to soil formation and long-term landscape change over time.

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Benchmark Clarifications:

Clarification 1: Instruction includes soil formation as a result of weathered rock material mixing with organic matter.

Clarification 2: Instruction includes the factors that influence soil development such as climate, parent material, living organisms, topography, and time.

Clarification 3: Instruction includes that surface processes operate over short- and long-time scales.

Clarification 4: Instruction includes that landscapes reflect the balance between weathering, erosion, deposition, and soil development.

Clarification 5: Instruction includes analyzing relationships among climate, topography, time, and rates of soil and landscape development. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining evidence from soil profiles, landforms, and landscape features to evaluate long-term surface change. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.4 Analyze how Earth's geosphere, hydrosphere, atmosphere, and biosphere interact to transfer matter and energy and support life on Earth.

SC.912.PE.4.1 Describe and classify how Earth’s spheres are defined by their physical components and roles within the Earth system.

Benchmark Clarifications:

Clarification 1: Instruction includes the geosphere, hydrosphere, atmosphere, and biosphere.

Clarification 2: Instruction includes using systems models to identify and represent the geosphere, hydrosphere, atmosphere, and biosphere and their interactions within the Earth system. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 3: Instruction includes examining historical developments related to the emergence of Earth system science and the understanding of interactions among Earth's

spheres. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.4.2 Trace how matter moves between Earth's spheres through interconnected cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes the hydrologic, carbon, nitrogen, and phosphorus cycles.

Clarification 2: Instruction includes that matter is conserved as it moves through and between spheres.

Clarification 3: Instruction includes the role of living organisms in the movement and transformation of matter through and between spheres.

Clarification 4: Instruction includes analyzing quantities, rates, and pathways associated with the movement of matter through Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes tracing the movement of matter among reservoirs and identifying pathways through interconnected Earth system cycles. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.4.3 Analyze how energy is transferred among Earth's spheres and drives Earth system interactions.

Benchmark Clarifications:

Clarification 1: Instruction includes the Sun as the primary source of energy for Earth's system.

Clarification 2: Instruction includes energy transfer through radiation, conduction, and convection.

Clarification 3: Instruction includes how energy movement influences weather, climate, ocean circulation, and biological productivity.

Clarification 4: Instruction includes that energy flows through Earth's systems and is ultimately released as heat to space.

Clarification 5: Instruction includes using models to represent energy transfer among Earth's spheres and interactions that influence weather, climate, ocean circulation, and biological productivity. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.4.4 Evaluate how interactions among Earth's spheres create conditions that support life.

Benchmark Clarifications:

Clarification 1: Instruction includes how the atmosphere regulates temperature and protects life from harmful radiation.

Clarification 2: Instruction includes how water availability and cycling support biological processes.

Clarification 3: Instruction includes how soil formation and nutrient availability link the geosphere and biosphere.

Clarification 4: Instruction includes that life depends on and modifies Earth system processes.

SC.912.PE.4.5 Assess the impacts of changes in one Earth sphere on other spheres and overall Earth system balance.

Example: Analyze a real-world scenario to determine whether interactions between Earth's spheres produce stabilizing feedbacks that reduce change or amplifying feedbacks that intensify change.

Example: Explain how a change in one Earth sphere causes measurable effects in at least one other sphere using cause-and-effect reasoning.

Benchmark Clarifications:

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Clarification 1: Instruction includes natural changes such as hurricanes, droughts, floods, and volcanic eruptions.

Clarification 2: Instruction includes anthropogenic changes such as deforestation, urbanization, pollution, and shifts in temperature and precipitation patterns.

Clarification 3: Instruction includes feedback mechanisms that can stabilize or amplify changes within and among Earth systems.

Clarification 4: Instruction includes using systems models to analyze how changes in one Earth sphere influence other spheres and overall Earth system balance. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing evidence from observations, monitoring records, maps, and data used to evaluate interactions among Earth systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.5 Analyze how Earth's atmosphere is structured, composed, and retained by gravity and how it regulates temperature, protects the surface, and enables weather.

SC.912.PE.5.1 Describe the composition of Earth's atmosphere and explain how gravitational force retains atmospheric gases around the planet.

Benchmark Clarifications:

Clarification 1: Instruction includes the components of Earth's atmosphere: nitrogen, oxygen, argon, carbon dioxide, and trace gases.

Clarification 2: Instruction includes that atmospheric composition is described by relative proportions rather than exact quantities.

Clarification 3: Instruction includes that Earth's gravity allows long-term retention of an atmosphere suitable for life.

Clarification 4: Instruction includes analyzing the relative proportions of atmospheric gases and their distribution within Earth's atmosphere. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 5: Instruction includes using models to represent the composition of Earth's atmosphere and the role of gravity in retaining atmospheric gases around the planet. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.5.2 Differentiate Earth's atmospheric layers based on changes in temperature and composition.

Example: Analyze a vertical profile or diagram of the atmosphere to explain how changes in temperature with increasing altitude are used to define and distinguish Earth's atmospheric layers.

Benchmark Clarifications:

Clarification 1: Instruction includes the troposphere, stratosphere, mesosphere, thermosphere, and exosphere.

Clarification 2: Instruction includes analyzing temperature changes with increasing altitude to distinguish atmospheric layers. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 3: Instruction includes using atmospheric profiles, diagrams, and models to represent the structure of Earth's atmosphere and changes in temperature with altitude. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes analyzing atmospheric data, profiles, and observations used to identify and distinguish Earth's atmospheric layers. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.5.3 Analyze how the atmosphere regulates Earth's temperature through energy absorption, reflection, and redistribution.

Example: Analyze an Earth heat budget diagram to explain how incoming solar radiation, atmospheric absorption and reflection, the greenhouse effect, and atmospheric circulation work together to regulate Earth's temperature and reduce day-night temperature extremes.

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Benchmark Clarifications:

Clarification 1: Instruction includes solar radiation as the primary energy input to Earth's atmosphere.

Clarification 2: Instruction includes the Greenhouse Effect as a natural process that retains heat near Earth's surface.

Clarification 3: Instruction includes the role of atmospheric circulation in redistributing heat from the equator to the poles.

Clarification 4: Instruction includes that atmospheric processes reduce extreme temperature differences between day and night.

Clarification 5: Instruction includes analyzing relationships among incoming solar radiation, reflected energy, absorbed energy, and thermal energy transfer within Earth's atmosphere. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using energy-budget diagrams and systems models to represent energy absorption, reflection, redistribution, and emission within Earth's atmosphere. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.5.4 Explain how the atmosphere protects Earth's surface from harmful external influences.

Example: Explain how Earth's atmosphere protects the surface of the planet by slowing and burning up most meteoroids during entry using diagrams or examples to connect this process to reduced surface impact and protection of life.

Benchmark Clarifications:

Clarification 1: Instruction includes the ozone layer's role in absorbing ultraviolet radiation.

Clarification 2: Instruction includes that atmospheric gases reduce exposure to harmful solar and cosmic radiation, providing protection that sustains life on Earth.

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Clarification 3: Instruction includes using models and diagrams to represent how atmospheric layers protect Earth from ultraviolet radiation, harmful solar radiation, and meteoroid impacts. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes examining historical developments related to the discovery of atmospheric layers, ultraviolet radiation, and the protective role of the ozone layer. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.5.5 Analyze how the atmosphere enables weather and influences short-term and long-term conditions at Earth's surface.

Benchmark Clarifications:

Clarification 1: Instruction includes weather conditions: temperature, precipitation, humidity, wind, and cloud cover.

Clarification 2: Instruction includes that weather results from differences in air pressure, temperature, and moisture.

Clarification 3: Instruction includes the role of water vapor and cloud formation in atmospheric processes.

Clarification 4: Instruction includes air masses, fronts, and their influence on temperature, humidity, cloud formation, precipitation, and severe weather.

Clarification 5: Instruction includes analyzing relationships among temperature, air pressure, moisture, wind patterns, and weather conditions. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using models to represent interactions among air masses, moisture, temperature, pressure, and weather conditions. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes analyzing weather observations, maps, satellite imagery, and atmospheric data used to investigate atmospheric conditions and weather patterns. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.5.6 Analyze weather data and forecasting products to predict short-term atmospheric conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes weather maps, isobars, pressure systems, fronts, radar imagery, satellite imagery, forecast models, and uncertainty in weather prediction.

SC.912.PE.5.7 Analyze how atmospheric pressure gradients and Earth's rotation influence wind patterns and weather.

Benchmark Clarifications:

Clarification 1: Instruction includes pressure gradients, the Coriolis effect, local winds, global winds, jet stream, trade winds, prevailing westerlies, and polar easterlies.

SC.912.PE.6 Analyze how the geologic time scale organizes Earth’s history and how rock layers, fossils, and key geologic events provide evidence for Earth's changing surface and life.

SC.912.PE.6.1 Describe the organization and use of the geologic time scale as a framework for understanding Earth’s history.

Benchmark Clarifications:

Clarification 1: Instruction includes the geologic time scale as a chronological system that divides Earth’s history into eons, eras, periods, and epochs.

Clarification 2: Instruction includes that divisions of the geologic time scale are based on changes in Earth’s surface conditions, climate, and life forms, including the first appearance or disappearance of major fossil groups.

Clarification 3: Instruction includes examining historical developments related to the development of the geologic time scale and the use of fossils and rock layers to organize

Earth's history. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.6.2 Analyze rock layers of now-extinct species to be used as relative-age indicators.

Example: Limestone layers are exposed during road construction in a North Florida karst region and along a nearby riverbank. Create and label cross-section diagrams showing sedimentary limestone layers and at least one cross-cutting feature at both locations. Use the visuals to determine relative ages and reconstruct the area’s shared geologic history.

Benchmark Clarifications:

Clarification 1: Instruction includes fossil content within sedimentary rock layers, including fossils of extinct organisms.

Clarification 2: Instruction includes principles of relative dating: superposition, original horizontality, cross-cutting relationships, and lateral continuity.

Clarification 3: Instruction includes analyzing spatial relationships among rock layers and geologic features to determine relative age relationships. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes constructing and interpreting cross sections and stratigraphic representations to determine relative ages and reconstruct geologic histories. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.6.3 Analyze how fossils provide evidence of past life and changes in Earth’s living organisms over time.

Example: Examine fossil assemblages from successive sedimentary rock layers and use written or visual representations to describe patterns over time and explain how the fossil record documents changes in environments and life across geologic time.

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Benchmark Clarifications:

Clarification 1: Instruction includes fossils as preserved remains, impressions, or traces of past living organisms most commonly found in sedimentary rocks.

Clarification 2: Instruction includes that fossil evidence shows changes in lifeforms over time including appearance, extinction, and diversification of species.

Clarification 3: Instruction includes analyzing fossil evidence to identify patterns of appearance, extinction, and diversification among organisms over geologic time. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.6.4 Evaluate how major geologic events mark changes in Earth's surface and life throughout Earth's history.

Example: Analyze quantitative fossil data in geologic timelines that include the appearance and disappearance of dinosaurs and Florida's transition from a shallow marine environment to a carbonate platform. Construct graphs representing time intervals between major geologic events on the geologic timescale, use algebraic reasoning to compare durations and rates of change, and explain how these model-patterns correspond to changes in Earth surface conditions and the types of living organisms present over geologic time.

Benchmark Clarifications:

Clarification 1: Instruction includes major events such as mass extinctions, mountain building, volcanism, and continental movement.

Clarification 2: Instruction includes that some geologic events occur gradually while others occur rapidly to alter Earth's physical environments and biological communities.

Clarification 3: Instruction includes that major events are used to find boundaries within the geologic time scale.

Clarification 4: Instruction includes analyzing durations, rates of change, and relationships among major geologic events across the geologic time scale. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 5: Instruction includes examining historical developments related to mass extinctions, continental movement, mountain building, and other major events used to interpret Earth's history. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.6.5 Synthesize information from multiple sources to interpret changes in Earth's surface and the living organisms present over geologic time.

Example: Organize Florida fossil evidence, such as shark teeth and marine shell fossils preserved in limestone, into a data table with rock layer and geologic age. Convert geologic time scale values using an appropriate scale, such as millions of years to centimeters on a timeline, to construct a graph or scaled timeline from the converted data. Integrate these representations with regional geologic event records to describe changes in Florida's landscapes and living organisms over geologic time.

Benchmark Clarifications:

Clarification 1: Instruction includes using information from rock layers, fossils (including fossils of extinct organisms), and major geologic events together to develop interpretations of Earth's history.

Clarification 2: Instruction includes that interpretations of Earth's past are based on physical evidence and scientific analysis rather than direct observation.

Clarification 3: Instruction includes that evidence indicates Earth's surface environments and the types of living organisms present have varied over geologic time, including the appearance and disappearance of species documented in the fossil record.

Clarification 4: Instruction includes comparing and integrating multiple sources of evidence to describe Earth's past and relate it to present-day landscapes, ecosystems, and Earth system.

Clarification 5: Instruction includes organizing, scaling, and interpreting geologic time, fossil, and event data using tables, graphs, timelines, and other quantitative representations. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 6: Instruction includes evaluating and synthesizing evidence from rock layers, fossils, geologic events, and other records to develop interpretations of Earth's history. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.7 Analyze how relative dating principles and radiometric dating methods are used to determine the ages of rocks, fossils, and past Earth events.

SC.912.PE.7.1 Analyze the sequence of rocks, fossils, and geologic events found on Earth from oldest to youngest using relative dating principles.

Benchmark Clarifications:

Clarification 1: Instruction includes relative dating principles: law of superposition, original horizontality, cross-cutting relationships, inclusions, fossil succession, and unconformities.

Clarification 2: Instruction includes interpretation of rock layers, geologic cross sections, and fossil distributions.

Clarification 3: Instruction includes that relative dating determines the order of events not numerical age.

Clarification 4: Instruction includes constructing and interpreting geologic cross sections and stratigraphic sequences to determine the order of geologic events. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing spatial relationships among rock layers, fossils, and geologic features to determine relative ages and event sequences. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.7.2 Explain and evaluate how index fossils are used to correlate rock layers across different locations on Earth.

Example: Examine rock layers from different locations and identify index fossils based on their short geologic range and wide geographic distribution to correlate the relative ages of

the layers. Explain how this method works on regional and global scales and describe at least one limitation of using fossils to correlate rock layers.

Benchmark Clarifications:

Clarification 1: Instruction includes that index fossils are organisms that were geographically widespread and existed for relatively short periods of geologic time.

Clarification 2: Instruction includes using index fossils to correlate rock layers and determine relative ages across different locations.

Clarification 3: Instruction includes limitations of fossil correlation such as incomplete fossil records and the absence of suitable index fossils.

Clarification 4: Instruction includes analyzing fossil distributions and rock-layer relationships to correlate geologic records across regions. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.7.3 Analyze how radiometric dating determines the absolute age of rocks and Earth materials.

Example: Describe how radiometric dating determines the absolute age of rocks by applying radioactive decay, half-life, and parent-to-daughter isotope ratios. Select the appropriate dating method and calculate sample age by determining the number of half-lives from given data and multiplying by the known half-life or interpreting the decay curve.

Example: Case Study – Archaeologists investigated a submerged prehistoric burial site near Manasota Key, off the coast of Venice, Florida, and determined the remains are approximately 7000 years old using carbon-14 dating. The human remains and associated organic materials contained carbon that began decaying after death, allowing scientists to measure the ratio of carbon-14 to carbon-12. Using the half-life of carbon-14, researchers calculated the absolute age of the site. This demonstrates how using radiometric dating can provide approximate numerical ages for Earth materials and biological remains in Florida's past.

Student Task(s) –

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- Explain why the carbon-14 dating was selected by scientists as the radiometric method for determining the age of the Manasota Key burial site.
- Analyze how radioactive decay and half-life are used by scientists to calculate the age of organic materials at this burial site.

Benchmark Clarifications:

Clarification 1: Instruction includes radioactive decay, half-lives, parent isotopes, and daughter isotopes.

Clarification 2: Instruction includes common radiometric dating methods such as carbon-14, potassium-argon (K-Ar), and uranium-lead (U-Pb) dating and their appropriate applications.

Clarification 3: Instruction includes calculating ages using radioactive decay, half-life relationships, parent isotopes, and daughter isotopes. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using decay curves, isotope relationships, and other models to represent radioactive decay and radiometric dating processes. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes examining historical developments related to radioactivity, isotopes, radioactive decay, and radiometric dating. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.7.4 Compare relative dating and radiometric dating methods by examining how each determines age and how they are used together to develop geologic time scales of Earth.

Benchmark Clarifications:

Clarification 1: Instruction includes that relative dating determines the sequence of events while radiometric dating provides approximate numerical ages.

Clarification 2: Instruction includes strengths and limitations of relative dating and radiometric dating methods.

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Clarification 3: Instruction includes how relative dating and radiometric dating are used together to develop and refine the geologic time scale.

Clarification 4: Instruction includes comparing relative and radiometric dating evidence to interpret Earth's history. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.7.5 Examine and analyze dating evidence to determine the timing and sequence of major Earth events.

Benchmark Clarifications:

Clarification 1: Instruction includes events such as volcanic eruptions, mass extinctions, and mountain building.

Clarification 2: Instruction includes using dating data to connect Earth events to changes in rock layers or fossil records.

Clarification 3: Instruction includes organizing and interpreting relative dating and radiometric dating evidence to determine the timing and sequence of major Earth events. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes evaluating multiple sources of dating evidence to support conclusions about the timing of major Earth events. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.7.6 Apply radiometric dating principles to determine the ages of Earth materials and geologic events.

SC.912.PE.8 Analyze how plate tectonics provides an integrated theory for earthquakes, volcanoes, mountain building, ocean basin formation, and continental motion.

SC.912.PE.8.1 Describe the fundamental principles of plate tectonic theory and explain how tectonic plates move.

Benchmark Clarifications:

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Clarification 1: Instruction includes the roles of mantle convection, slab pull, and ridge push as mechanisms that contribute to plate motion.

Clarification 2: Instruction includes using models to represent tectonic plates, plate boundaries, and mechanisms associated with plate movement. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 3: Instruction includes examining historical developments related to continental drift, seafloor spreading, and plate tectonic theory. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.8.2 Analyze how interactions at tectonic plate boundaries result in earthquakes.

Example: Analyze earthquake distribution data alongside tectonic plate boundary maps to explain how stress accumulation and sudden energy release along faults cause earthquakes at transform, convergent, and divergent boundaries. Using evidence from earthquake depth, magnitude, and location patterns, students construct a cause-and-effect explanation for why most earthquakes occur at plate boundaries and how boundary type influences earthquake characteristics.

Benchmark Clarifications:

Clarification 1: Instruction includes transform, convergent, and divergent plate boundaries.

Clarification 2: Instruction includes that the depth, magnitude, and distribution of earthquakes vary depending on the plate boundary type.

Clarification 3: Instruction includes analyzing earthquake depth, magnitude, frequency, and distribution patterns associated with tectonic plate boundaries. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using plate boundary maps, fault models, and tectonic models to explain the relationship between plate interactions and earthquake occurrence. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 5: Instruction includes analyzing earthquake data and geologic evidence used to explain the distribution of earthquakes at plate boundaries. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.8.3 Analyze how plate tectonic processes lead to volcanic activity.

Example: Analyze volcano distribution and tectonic plate boundary maps to explain how magma generation at convergent and divergent boundaries forms volcanic arcs, using the Pacific Ring of Fire as evidence that subduction-dominated plate interactions concentrate volcanic activity in specific regions.

Benchmark Clarifications:

Clarification 1: Instruction includes magma generation at convergent boundaries due to subduction and partial melting.

Clarification 2: Instruction includes volcanic activity at divergent boundaries associated with decompression melting.

Clarification 3: Instruction includes that volcanic distributions are used as evidence for plate boundaries and plate motion.

Clarification 4: Instruction includes hot spots as volcanic features that provide additional evidence of plate movement.

Clarification 5: Instruction includes using plate boundary maps, cross-sectional diagrams, and tectonic models to represent magma generation and volcanic activity. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing volcanic distributions and geologic evidence used to support explanations of plate motion and plate boundary interactions. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.8.4 Analyze how plate tectonic interactions result in mountain building and crustal deformation.

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Benchmark Clarifications:

Clarification 1: Instruction includes mountain building through continental-continental plate convergence and crustal shortening.

Clarification 2: Instruction includes processes such as folding, faulting, uplift, and thickening of the crust.

Clarification 3: Instruction includes using cross-sectional and tectonic models to represent crustal deformation, folding, faulting, uplift, and mountain building. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes examining evidence from rock layers, geologic structures, and mountain belts used to explain crustal deformation and mountain building processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.8.5 Analyze how plate tectonics account for the formation and recycling of ocean basins.

Benchmark Clarifications:

Clarification 1: Instruction includes sea floor spreading as the geologic process that creates new oceanic crust.

Clarification 2: Instruction includes subduction as the geologic process that recycles oceanic lithosphere.

Clarification 3: Instruction includes that ocean floor age is a function of distance from mid-ocean ridges with crustal age increasing as distance increases.

Clarification 4: Instruction includes analyzing relationships between ocean-floor age, distance from mid-ocean ridges, and plate movement. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using models and ocean-floor age data to explain the formation and recycling of ocean basins. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.8.6 Evaluate how plate tectonics account for the movement of continents over Earth's surface.

Benchmark Clarifications:

Clarification 1: Instruction includes that continents move as part of larger tectonic plates rather than independently as continents.

Clarification 2: Instruction includes that continental motion occurs over geologic time as a result of plate movement driven by internal Earth processes.

Clarification 3: Instruction includes evidence of continental motion such as the matching shapes of continents, fossil distribution, rock formation, and past environmental conditions.

Clarification 4: Instruction includes using models to represent continental motion and changes in continental positions over geologic time. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using fossil distributions, rock formations, and continental configurations as evidence to reconstruct past continental positions. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to continental drift, seafloor spreading, and the acceptance of plate tectonic theory. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.9 Analyze how heat from Earth's interior drives mantle convection, plate motion, volcanism, and the recycling of Earth's crust.

SC.912.PE.9.1 Identify and describe sources of heat within Earth's interior.

Benchmark Clarifications:

Clarification 1: Instruction includes residual heat from Earth's formation and heat from radioactive decay.

Clarification 2: Instruction includes that heat from Earth's interior is transferred toward the surface and drives internal Earth processes.

Clarification 3: Instruction includes examining historical developments related to radioactive decay and its role in understanding Earth's internal heat source. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.9.2 Analyze how internal heat drives mantle convection.

Example: Construct and observe a liquid density column to model how temperature-driven density differences cause material to move simulating mantle convection within Earth. By comparing the motion of warmer, less dense fluid and cooler, denser fluids explain how internal heat generates convection currents that transfer energy and drive large-scale Earth processes.

Benchmark Clarifications:

Clarification 1: Instruction includes density differences caused by temperature variation.

Clarification 2: Instruction includes that warmer, less dense material rises while cooler, denser material sinks, producing convection currents that transfer thermal energy.

Clarification 3: Instruction includes analyzing relationships among temperature, density, and material movement within Earth's mantle. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using physical, conceptual, and computational models to represent mantle convection and energy transfer within Earth's interior. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing observations, investigations, simulations, and models used to explain convection-driven movement within Earth. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.9.3 Analyze how mantle convection contributes to plate motion and volcanism.

Benchmark Clarifications:

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Clarification 1: Instruction includes mantle convection as a mechanism that contributes to tectonic plate movement.

Clarification 2: Instruction includes that mantle convection influences magma formation, volcanism, and the movement of lithospheric plates.

Clarification 3: Instruction includes connections among mantle convection, plate boundaries, volcanic activity, and surface features.

Clarification 4: Instruction includes using models to represent relationships among mantle convection, plate motion, and volcanism. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.9.4 Analyze how heat-driven processes recycle Earth's crust.

Example: Analyze ocean-floor age and plate boundary maps of the Atlantic Ocean adjacent to the Florida coast to identify patterns of crust formation and movement. Using this data, explain how heat-driven plate motion produces seafloor spreading at mid-ocean ridges and leads to the long-term recycling of oceanic crust through subduction, demonstrating how Earth's crust is continuously renewed over geologic time.

Benchmark Clarifications:

Clarification 1: Instruction includes seafloor spreading as a process that forms new oceanic crust at mid-ocean ridges.

Clarification 2: Instruction includes subduction as a process that recycles oceanic crust into Earth's interior.

Clarification 3: Instruction includes that crustal recycling is driven by internal heat and plate motion over geologic time.

Clarification 4: Instruction includes analyzing relationships among ocean-floor age, distance from mid-ocean ridges, and plate movement. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 5: Instruction includes using plate boundary maps, ocean-floor age data, and tectonic models to explain crust formation and recycling. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.10 Analyze how Earth's magnetic field is generated by core processes and how the magnetosphere protects Earth and supports navigation.

SC.912.PE.10.1 Describe the structure of Earth's core.

Benchmark Clarifications:

Clarification 1: Instruction includes that Earth's core is divided into a solid inner core and liquid outer core.

Clarification 2: Instruction includes that Earth's core is composed primarily of iron and nickel.

Clarification 3: Instruction includes the differences between the inner and outer core based on temperature, pressure, and physical state.

Clarification 4: Instruction includes using models to represent the structure of Earth's core and the relationships among composition, temperature, pressure, and physical state. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.10.2 Analyze how motion in the outer core generates the Earth's magnetic field.

Benchmark Clarifications:

Clarification 1: Instruction includes that movement of molten, electrically conductive iron in Earth's liquid outer core generates electric currents.

Clarification 2: Instruction includes that the combination of core motion and Earth's rotation produces a magnetic field through the geodynamo process.

Clarification 3: Instruction includes that Earth's magnetic field is continuously generated and maintained, not static.

Clarification 4: Instruction includes using diagrams and models to represent the geodynamo process and the generation of Earth's magnetic field. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing geophysical evidence used to infer processes occurring within Earth's outer core. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to magnetism, electromagnetism, and the development of geodynamo theory. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.10.3 Analyze how the magnetosphere protects Earth from solar radiation.

Example: Earth’s magnetosphere helps protect spacecraft and satellites associated with Florida launches by deflecting charged particles from the solar wind that could otherwise disrupt spacecraft electronics during launch and early orbit. The protection reduces the risk of radiation damage to rockets, satellites, guidance systems, and communication signals. Explain why this is especially important for launches from Cape Canaveral where spacecraft pass through Earth’s upper atmosphere and near-Earth space during deployment.

Benchmark Clarifications:

Clarification 1: Instruction includes that Earth’s magnetic field creates a magnetosphere extending into space.

Clarification 2: Instruction includes that the magnetosphere deflects and redirects charged particles from the solar wind.

Clarification 3: Instruction includes that this protection helps preserve Earth’s atmosphere and reduces harmful radiation from reaching the surface.

Clarification 4: Instruction includes using models to represent interactions among Earth's magnetic field, magnetosphere, and charged particles from the solar wind. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.10.4 Apply knowledge of Earth’s magnetic field to explain how navigation is supported.

Benchmark Clarifications:

Clarification 1: Instruction includes that compasses align with Earth’s magnetic field allowing for the determination of direction.

Clarification 2: Instruction includes that patterns of magnetic orientation in rocks provide evidence of past magnetic field behavior.

Clarification 3: Instruction includes collecting and analyzing compass observations and directional data to determine how Earth's magnetic field supports navigation. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes examining historical developments related to magnetic navigation, compass use, and understanding Earth's magnetic field. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11 Analyze how water moves through Earth's systems, redistributes heat and matter, shapes Earth's surface, and influences weather, climate, freshwater systems, ocean systems, and ecosystem processes. A

SC.912.PE.11.1 Trace how matter moves through the hydrologic cycle to redistribute matter and energy.

Benchmark Clarifications:

Clarification 1: Instruction includes evaporation, transpiration, condensation, precipitation, infiltration, runoff, and groundwater flow.

Clarification 2: Instruction includes that water moves between the atmosphere, hydrosphere, geosphere, and biosphere.

Clarification 3: Instruction includes freshwater systems such as lakes, ponds, streams, rivers, wetlands, springs, and reservoirs as components of the hydrologic cycle.
Clarification 4: Instruction includes using system models to trace the movement of water

among Earth's spheres through the hydrologic cycle. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11.2 Analyze how the hydrologic cycle transfers heat within the Earth's system.

Benchmark Clarifications:

Clarification 1: Instruction includes the absorption of heat during evaporation and the release of heat during condensation.

Clarification 2: Instruction includes that these energy transfers influence atmospheric temperature and circulation.

Clarification 3: Instruction includes analyzing relationships among phase changes, heat transfer, and atmospheric conditions within the hydrologic cycle. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using models to represent the transfer of heat associated with evaporation, condensation, and movement of water through Earth's systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11.3 Analyze how ocean circulation redistributes heat and matter across the Earth.

Benchmark Clarifications:

Clarification 1: Instruction includes surface ocean currents driven by wind and Earth's rotation.

Clarification 2: Instruction includes deep ocean circulation driven by differences in temperature and salinity.

Clarification 3: Instruction includes that ocean circulation transports heat, nutrients, and dissolved substances.

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Clarification 4: Instruction includes the Gulf Stream, thermohaline circulation, upwelling, and downwelling and their influence on nutrient distribution, biological productivity, and regional climate.

Clarification 5: Instruction includes the influence of ocean currents on larval dispersal, migration, population connectivity, species distribution, biodiversity, and ecosystem productivity..

Clarification 6: Instruction includes analyzing the relationships among salinity, temperature, nutrient availability, dissolved oxygen, and biological productivity using oceanographic datasets. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes developing and using models to explain relationships among ocean circulation, climate regulation, nutrient transport, and ecosystem productivity. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 8: Instruction includes examining historical developments related to ocean circulation and the role of oceans in redistributing heat throughout Earth's system. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11.4 Analyze how the hydrologic cycle and ocean circulation influence weather patterns.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of moisture and heat transfer in cloud formation, storms, and precipitation.

Clarification 2: Instruction includes the interactions between oceans and atmosphere that affect short-term weather conditions.

Clarification 3: Instruction includes using models to represent interactions among ocean circulation, atmospheric processes, and weather systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.11.5 Evaluate how the hydrologic cycle and ocean circulation influence long-term patterns of temperature and precipitation over time.

Benchmark Clarifications:

Clarification 1: Instruction includes ocean heat storage and the redistribution of energy within the Earth's system.

Clarification 2: Instruction includes the interactions between oceans and atmosphere that influence long-term temperature and precipitation patterns.

Clarification 3: Instruction includes analyzing long-term temperature, precipitation, and ocean circulation data to identify patterns and trends. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 4: Instruction includes using models to represent interactions among ocean circulation, atmospheric processes, and long-term climate patterns. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes El Niño-Southern Oscillation (ENSO) and La Niña as examples of ocean-atmosphere interactions that influence regional and global patterns of temperature, precipitation, drought, flooding, and storm activity.

Clarification 6: Instruction includes the influence of El Niño and La Niña on Florida precipitation patterns, drought frequency, severe weather, and tropical cyclone activity.

SC.912.PE.11.6 Explain how water-driven processes shape Earth's surface.

Benchmark Clarifications:

Clarification 1: Instruction includes weathering, erosion, transport, and deposition by water.

Clarification 2: Instruction includes surface features such as river systems, deltas, flood plains, beaches, and coastlines.

Clarification 3: Instruction includes coastal processes such as wave action, longshore transport, tidal influences, barrier island formation, inlet migration, and shoreline change.

Clarification 4: Instruction includes interactions among waves, tides, currents, storm surge, and sediment transport that influence beach profiles, inlet dynamics, barrier-island migration, and long-term shoreline change.

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Clarification 5: Instruction includes littoral drift as the movement of sediment parallel to shore and its role in shoreline accretion, erosion, spit formation, barrier-island migration, and inlet development.

Clarification 6: Instruction includes wave generation, wave energy transfer, wave refraction, diffraction, and breaking waves and their influence on marine organisms, sediment transport, and coastal environments.

Clarification 7: Instruction includes barrier islands as dynamic coastal systems that provide habitat, support biodiversity, influence sediment transport and estuarine conditions, and reduce storm impacts.

Clarification 8: Instruction includes relationships among sediment transport, wave energy, habitat formation, biodiversity, organism distribution, and ecosystem productivity.

Clarification 9: Instruction includes Florida examples such as barrier islands, estuaries, beaches, dunes, and coastal wetlands.

Clarification 10: Instruction includes using models to represent how moving water shapes Earth's surface and produces landforms over time. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11.7 Synthesize data to explain how the hydrologic cycle and ocean circulation operate as interconnected Earth systems.

Example: Analyze Florida specific data and maps including rainfall patterns, hurricane tracks, Gulf Stream maps, sea surface temperature data, and watershed maps to explain how the hydrologic cycle and ocean circulation operate as interconnected Earth systems affecting Florida. Using this data construct an explanation demonstrating how changes in one part of the system can affect other components including weather patterns, coastal processes, and freshwater availability across the state.

Benchmark Clarifications:

Clarification 1: Instruction includes synthesizing multiple sources of data and evidence to explain interactions among the hydrologic cycle, ocean circulation, atmosphere, and Earth's surface.Clarification 2: Instruction includes evaluating interactions among

watersheds, estuaries, nearshore systems, and open-ocean environments as interconnected Earth systems.

Clarification 3: Instruction includes synthesizing oceanic and atmospheric datasets associated with El Niño-Southern Oscillation (ENSO) and La Niña to explain interactions among ocean circulation, weather, and climate systems.

Clarification 4: Instruction includes analyzing relationships among rainfall patterns, ocean currents, sea surface temperatures, storm activity, watersheds, and other Earth system components. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using systems models to represent interactions among the hydrologic cycle, ocean circulation, weather, and Earth's surface processes. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing observations, maps, monitoring records, satellite imagery, and other data sources used to investigate interactions among Earth systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11.8 Analyze how the physical and chemical properties of seawater influence ocean circulation, ecosystem productivity, and the distribution of marine organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes salinity, temperature, density, dissolved gases, nutrients, and pH.

Clarification 2: Instruction includes relationships among seawater properties, ocean circulation, and marine biodiversity.

Clarification 3: Instruction includes ocean acidification and carbon cycling within marine systems.

Clarification 4: Instruction includes relationships among seawater chemistry, primary productivity, calcification, photosynthesis, respiration, reproduction, symbiosis, species distribution, and ecosystem structure.

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Clarification 5: Instruction includes analyzing oceanographic datasets to investigate relationships among seawater properties and marine environments. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes developing and using models that explain interactions among seawater chemistry, circulation, and biological systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.11.9 Analyze how the physical and chemical characteristics of freshwater systems influence biological productivity and organism distribution.

Benchmark Clarifications:

Clarification 1: Instruction includes littoral, limnetic, profundal, and benthic zones.

Clarification 2: Instruction includes light availability, temperature gradients, dissolved oxygen distribution, nutrient availability, turbidity, and their influence on primary productivity and organism distribution.

Clarification 3: Instruction includes relationships among freshwater zones and biological productivity.

Clarification 4: Instruction includes lakes, ponds, reservoirs, rivers, streams, and wetlands as freshwater systems with differing physical and biological characteristics.

Clarification 5: Instruction includes relationships among nutrient availability, primary productivity, algal growth, dissolved oxygen, and trophic conditions in freshwater systems.

Clarification 6: Instruction includes pH, conductivity, alkalinity, and dissolved minerals as indicators of freshwater ecosystem conditions.

Clarification 7: Instruction includes wetlands as freshwater systems that support biodiversity, nutrient retention, groundwater recharge, water storage, and water-quality improvement.

Clarification 8: Instruction includes differences among lentic systems (lakes and ponds) and lotic systems (rivers and streams).

SC.912.PE.11.10 Analyze thermal stratification and seasonal mixing processes in freshwater systems.

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Example: Analyze temperature and dissolved oxygen profiles from Florida lakes.

Example: Evaluate effects of turnover on nutrient availability and biological productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes epilimnion, metalimnion, thermocline, and hypolimnion.

Clarification 2: Instruction includes thermal stratification, autumn and spring turnover, and dissolved oxygen distribution.

Clarification 3: Instruction includes nutrient cycling associated with mixing processes.

Clarification 4: Instruction includes relationships among thermal stratification, nutrient availability, dissolved oxygen, species distribution, primary productivity, and ecosystem function.

SC.912.PE.11.11 Analyze interactions among groundwater systems, karst landscapes, springs, and freshwater ecosystems.

Example: Analyze maps, groundwater-flow data, cave-survey information, and water-quality measurements from the Wakulla Springs system to explain how water moves through the Floridan Aquifer and connected underground cave networks. Evaluate how groundwater recharge, nutrient transport, land use, and karst processes influence spring discharge, water quality, biodiversity, and freshwater ecosystem health.

Benchmark Clarifications:

Clarification 1: Instruction includes the Floridan Aquifer, groundwater flow, recharge, discharge, and spring systems.

Clarification 2: Instruction includes karst processes, sinkhole formation, dissolution of limestone, and groundwater-surface water interactions.

Clarification 3: Instruction includes relationships among groundwater quality, spring ecosystems, biodiversity, and human activities.

Clarification 4: Instruction includes evaluating the effects of land use, groundwater withdrawal, contamination, and nutrient inputs on springs and connected freshwater ecosystems.

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Clarification 5: Instruction includes spring ecosystems, submerged aquatic vegetation, endemic species, and ecological responses to changing water quality.

SC.912.PE.11.12 Analyze how watersheds influence water movement, water quality, nutrient transport, and freshwater ecosystem function.

Benchmark Clarifications:

Clarification 1: Instruction includes watersheds, drainage basins, surface-water systems, groundwater recharge areas, and watershed boundaries.

Clarification 2: Instruction includes relationships among precipitation, runoff, infiltration, groundwater flow, and water storage within watersheds.

Clarification 3: Instruction includes transport of sediments, nutrients, contaminants, and organic matter through watershed systems.

Clarification 4: Instruction includes how land use, urbanization, agriculture, and vegetation influence water quality, hydrology, and ecosystem processes.

Clarification 5: Instruction includes relationships among watersheds, rivers, lakes, wetlands, springs, estuaries, and coastal ecosystems.

Clarification 6: Instruction includes analyzing hydrologic, water-quality, and geospatial datasets to evaluate watershed processes and ecosystem health. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes using systems models to represent interactions among watershed components, freshwater systems, and downstream environments. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 8: Instruction includes analyzing observations, maps, monitoring records, remote sensing data, and geographic information system (GIS) products used to investigate watershed processes and environmental change. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 9: Instruction includes spring-shed and watershed relationships within Florida karst and aquifer systems.

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SC.912.PE.11.13 Analyze factors that influence productivity and water quality in freshwater ecosystems.

Example: Analyze lake data to determine relationships among nutrient concentrations, dissolved oxygen, algal growth, and ecosystem productivity.

Example: Compare oligotrophic, mesotrophic, and eutrophic lakes using biological and chemical datasets.

Benchmark Clarifications:

Clarification 1: Instruction includes primary productivity, nutrient availability, dissolved oxygen, and light penetration.

Clarification 2: Instruction includes oligotrophic, mesotrophic, and eutrophic freshwater systems.

Clarification 3: Instruction includes eutrophication and harmful algal blooms.

Clarification 4: Instruction includes relationships among productivity, biodiversity, and ecosystem health.

Clarification 5: Instruction includes Secchi depth, water clarity, and turbidity as indicators of productivity and water quality in freshwater ecosystems.

SC.912.PE.12 Analyze how Earth scientists use seismic waves, geochemical data, and geophysical measurements to infer Earth's internal structure and dynamic processes.

SC.912.PE.12.1 Analyze how seismic wave evidence is used to infer Earth's internal structure and properties.

Example: Analyze global seismic wave records from multiple earthquake locations to determine how changes in wave speed, refraction, and shadow zones provide evidence for Earth's layered interior.

Benchmark Clarifications:

Clarification 1: Instruction includes that seismic waves are generated by earthquakes and travel at different speeds depending on the material they pass through.

Clarification 2: Instruction includes distinctions between P-waves and S-waves including how their motion and ability or inability to travel through liquids provide evidence about material states.

Clarification 3: Instruction includes that changes in wave speed, refraction, reflection, and shadow zones provide evidence for layered internal structures within Earth.

Clarification 4: Instruction includes that seismic data are used to infer the boundaries between Earth's layers: the crust, mantle, outer core, and inner core.

Clarification 5: Instruction includes analyzing relationships among seismic wave velocity, travel time, distance, and Earth materials. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing seismic records and other evidence used to infer Earth's internal structure. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.12.2 Analyze how geochemical evidence from rocks and volcanic materials is used to infer Earth's internal composition and processes.

Benchmark Clarifications:

Clarification 1: Instruction includes that Earth's interior cannot be sampled directly and that scientists use geochemical evidence from surface rocks and volcanic materials to infer internal composition.

Clarification 2: Instruction includes that igneous rocks and volcanic gases provide evidence of mantle and crust composition.

Clarification 3: Instruction includes that differences in elemental and isotopic composition reflect processes such as heat-driven melting, differentiation, and recycling of Earth materials.

Clarification 4: Instruction includes that meteorites are used as comparative evidence for Earth's bulk composition and early formation.

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Clarification 5: Instruction includes analyzing geochemical evidence from rocks, volcanic materials, gases, and meteorites to infer Earth's composition and internal processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.12.3 Analyze how geophysical measurements are used to infer Earth's internal properties and dynamic behavior.

Benchmark Clarifications:

Clarification 1: Instruction includes measurements of gravity, magnetism, and heat flow as tools for investigating Earth's interior.

Clarification 2: Instruction includes that variations in gravitational measurements provide evidence of density differences within the Earth.

Clarification 3: Instruction includes that magnetic field measurements are used to infer properties of Earth's liquid outer core and past plate motion.

Clarification 4: Instruction includes that heat flow measurements provide evidence of internal heat sources and energy transfer from Earth's interior.

Clarification 5: Instruction includes analyzing relationships among gravity, magnetism, heat flow, density, and Earth structure using quantitative data. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes evaluating geophysical measurements used to infer Earth's internal properties and dynamic behavior. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.12.4 Analyze how Earth scientists use models to represent Earth's internal structure and dynamic processes.

Benchmark Clarifications:

Clarification 1: Instruction includes physical, mathematical, and computer-based models used to represent processes that cannot be directly observed.

Clarification 2: Instruction includes seismic velocity models, mantle convection models, and magnetic field models.

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Clarification 3: Instruction includes that models are based on available evidence and are refined as new data become available.

Clarification 4: Instruction includes evaluating how well models explain observed Earth system phenomena such as plate motion, volcanism, and seismic patterns.

Clarification 5: Instruction includes examining historical developments related to seismic-wave analysis, Earth's internal structure, mantle convection, and geophysical models. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.12.5 Synthesize seismic, geochemical, and geophysical evidence to explain Earth’s internal structure and dynamic processes.

Benchmark Clarifications:

Clarification 1: Instruction includes integrating data from seismic waves, rock composition, gravity, magnetism, and heat flow.

Clarification 2: Instruction includes that no single type of evidence fully explains Earth’s interior and that conclusions are strengthened by multiple independent data sources.

Clarification 3: Instruction includes using multiple lines of evidence to explain processes such as mantle convection, plate tectonics, and crustal recycling.

Clarification 4: Instruction includes that scientific explanations of Earth’s interior are built through synthesis rather than direct observation.

Clarification 5: Instruction includes synthesizing multiple sources of quantitative evidence to explain Earth's internal structure and dynamic processes. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes evaluating and integrating multiple lines of evidence to support explanations of Earth's interior. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.12.6 Evaluate the strengths and limitations of using indirect evidence to study Earth’s interior.

Benchmark Clarifications:

Clarification 1: Instruction includes that Earth's deep interior cannot be directly accessed with current technology.

Clarification 2: Instruction includes that indirect evidence requires interpretation and may contain uncertainty.

Clarification 3: Instruction includes that scientific conclusions about Earth's interior are subject to revision as new data become available.

Clarification 4: Instruction includes distinguishing between observation, inference, and scientific modeling in Earth science investigations.

Clarification 5: Instruction includes examining historical developments that improved scientific understanding of Earth's interior through seismic, geochemical, and geophysical evidence. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.13 Analyze how Earth's atmosphere and oceans regulate climate through radiation balance, greenhouse processes, feedback mechanisms, and large-scale circulation.

SC.912.PE.13.1 Analyze how the balance between incoming solar radiation and outgoing energy regulates Earth's climate.

Benchmark Clarifications:

Clarification 1: Instruction includes incoming solar radiation as Earth's primary energy source.

Clarification 2: Instruction includes reflection, absorption, and re-emission of energy by Earth's surface, atmosphere, and clouds.

Clarification 3: Instruction includes albedo and how surface characteristics such as ice, water, land and clouds affect reflected energy.

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Clarification 4: Instruction includes that Earth’s average temperature is regulated by maintaining a balance between absorbed and emitted energy.

Clarification 5: Instruction includes analyzing relationships among incoming solar radiation, reflected energy, absorbed energy, and emitted energy within Earth's climate system. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using energy-budget diagrams and systems models to represent radiation balance within Earth's climate system. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.13.2 Analyze how greenhouse processes influence Earth’s temperature and climate patterns.

Benchmark Clarifications:

Clarification 1: Instruction includes greenhouse gases such as water vapor, carbon dioxide, methane, and nitrous oxide.

Clarification 2: Instruction includes that greenhouse gases absorb and re-emit infrared radiation.

Clarification 3: Instruction includes the greenhouse effect as a natural process essential for maintaining habitable surface temperatures.

Clarification 4: Instruction includes that changes in greenhouse gas concentrations influence Earth’s energy balance and climate conditions.

Clarification 5: Instruction includes using models to represent interactions among greenhouse gases, infrared radiation, and Earth's energy balance. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to greenhouse processes, radiation balance, and atmospheric composition. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.13.3 Analyze how large-scale atmospheric circulation redistributes heat and influences global climate patterns.

Benchmark Clarifications:

Clarification 1: Instruction includes global circulation cells: Hadley, Ferrel, and Polar cells.

Clarification 2: Instruction includes the role of Earth's rotation and pressure differences in driving atmospheric circulation.

Clarification 3: Instruction includes how atmospheric circulation redistributes heat from equatorial regions toward the poles.

Clarification 4: Instruction includes the influence of circulation patterns on regional temperature and precipitation trends.

Clarification 5: Instruction includes using circulation maps, diagrams, and atmospheric models to represent global atmospheric circulation patterns and heat transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.13.4 Analyze how ocean circulation contributes to climate regulation through heat storage and redistribution.

Benchmark Clarifications:

Clarification 1: Instruction includes ocean heat capacity and the ability of water to store large amounts of thermal energy.

Clarification 2: Instruction includes surface currents driven by wind and Earth's rotation.

Clarification 3: Instruction includes deep ocean circulation driven by temperature and salinity differences.

Clarification 4: Instruction includes that ocean circulation moderates regional and global climate by redistributing heat over long timescales.

Clarification 6: Instruction includes analyzing relationships among ocean temperature, salinity, circulation patterns, and heat transport. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 7: Instruction includes using circulation maps and ocean system models to represent heat storage and redistribution within Earth's climate system. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.13.5 Evaluate how feedback mechanisms influence Earth’s climate system.

Benchmark Clarifications:

Clarification 1: Instruction includes positive feedbacks that amplify change and negative feedbacks that reduce change such as ice-albedo feedback and vegetation-related feedbacks.

Clarification 2: Instruction includes that feedbacks influence the stability or variability of Earth’s climate system.

Clarification 3: Instruction includes that feedback mechanisms operate over different spatial and temporal scales.

Clarification 4: Instruction includes using systems models to represent feedback mechanisms and their influence on climate stability and change. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.13.6 Synthesize how radiation balance, greenhouse processes, circulation patterns, and feedbacks interact to regulate Earth’s climate.

Benchmark Clarifications:

Clarification 1: Instruction includes climate regulation results from interactions among multiple Earth systems rather than a single process.

Clarification 2: Instruction includes integrating atmospheric and oceanic processes to explain observed climate patterns.

Clarification 3: Instruction includes using data representations such as energy budget diagrams, circulation maps, and temperature patterns to support explanations.

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Clarification 4: Instruction includes that Earth's climate system is dynamic, responsive to change, and regulated through interacting processes.

Clarification 5: Instruction includes analyzing climate data, energy-budget diagrams, circulation maps, temperature records, and other quantitative representations to support explanations of climate regulation. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using systems models to represent interactions among radiation balance, greenhouse processes, circulation patterns, and climate feedbacks. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.13.7 Analyze how large-scale climate oscillations influence regional and global weather and climate patterns.

Example: Analyze sea surface temperature, atmospheric pressure, and precipitation datasets associated with El Niño and La Niña events to explain changes in weather patterns across Florida and North America.

Example: Evaluate relationships among the North Atlantic Oscillation, Atlantic Multidecadal Variability, hurricane activity, drought frequency, and long-term climate variability.

Benchmark Clarifications:

Clarification 1: Instruction includes El Niño-Southern Oscillation (ENSO), La Niña, the North Atlantic Oscillation (NAO), and Atlantic Multidecadal Variability (AMV).

Clarification 2: Instruction includes interactions among ocean circulation, sea surface temperatures, atmospheric circulation, jet-stream patterns, and climate patterns.

Clarification 3: Instruction includes relationships among climate oscillations, temperature patterns, precipitation patterns, drought, flooding, severe weather, and tropical cyclone activity.

Clarification 4: Instruction includes regional and global effects of climate oscillations on weather and climate systems.

Clarification 5: Instruction includes influences of ENSO, NAO, and AMV on Florida precipitation patterns, drought frequency, hurricane activity, and severe weather conditions.

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Clarification 6: Instruction includes analyzing long-term climate datasets to identify patterns associated with climate oscillations and evaluate relationships among ocean conditions, atmospheric processes, and climate variability. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes developing and using models to explain interactions among ocean circulation, atmospheric circulation, climate oscillations, and regional climate variability. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 8: Instruction includes analyzing observations, maps, climate records, and ocean-atmosphere datasets used to investigate climate oscillations and climate variability. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.14 Analyze how biogeochemical cycles move essential elements through Earth systems and how life both depends on and alters these cycles.

SC.912.PE.14.1 Analyze how essential elements move through Earth systems via biogeochemical cycles.

Example: Analyze data and fossil evidence from extinct Florida reef-building organisms (such as extinct coral and shell-forming species) to explain how their absence altered carbon and carbonate cycling rates and long-term element storage across Earth's systems.

Benchmark Clarifications:

Clarification 1: Instruction includes biogeochemical cycles: carbon, nitrogen, phosphorus, and hydrologic cycles.

Clarification 2: Instruction includes that biogeochemical cycles move matter through the atmosphere, hydrosphere, geosphere, and biosphere.

Clarification 3: Instruction includes that matter is conserved as it changes form and location within and between Earth systems.

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Clarification 4: Instruction includes that cycling rates vary among elements and reservoirs and may be influenced by the presence, absence, or loss of organisms that serve as major sinks or pathways for those elements.

Clarification 5: Instruction includes marine reservoirs of carbon, including ocean waters, marine sediments, carbonate platforms, coral reefs, and shell-producing organisms.

Clarification 6: Instruction includes analyzing the movement of matter among reservoirs and comparing cycling rates among elements and Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes using systems models to trace the movement of elements through interconnected biogeochemical cycles. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.14.2 Analyze how biological processes drive the movement and transformation of matter within biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes biological processes: photosynthesis, respiration, decomposition, and nutrient uptake.

Clarification 2: Instruction includes that living organisms transform elements into different chemical forms.

Clarification 3: Instruction includes that ecosystems depend on the availability and cycling of essential elements, and that changes in organism populations, including the loss or reduction of key species, can alter these cycling pathways.

Clarification 4: Instruction includes that biological activity links the biosphere with other Earth systems.

Clarification 5: Instruction includes using models to represent how photosynthesis, respiration, decomposition, and nutrient uptake influence the movement and transformation of matter within biogeochemical cycles. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.14.3 Analyze how geological and physical Earth processes influence biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes weathering, erosion, sedimentation, and volcanic activity as processes that move elements through the geosphere.

Clarification 2: Instruction includes ocean circulation and atmospheric transport as mechanisms for redistributing matter.

Clarification 3: Instruction includes differences in cycling timescales, from rapid biological cycling to slow geologic cycling.

Clarification 4: Instruction includes that Earth's internal and surface processes influence long-term availability of essential elements, including changes associated with the disappearance of organisms that previously contributed to element storage in sediments or landforms.

Clarification 5: Instruction includes ocean circulation, coastal upwelling, sedimentation, and marine productivity as factors influencing biogeochemical cycling.

Clarification 6: Instruction includes analyzing differences in biological and geologic cycling timescales and the movement of matter among Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes using systems models to represent interactions among geologic, physical, and biological processes within biogeochemical cycles. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.14.4 Evaluate how interactions within and among biogeochemical cycles influence Earth system stability.

Benchmark Clarifications:

Clarification 1: Instruction includes that biogeochemical cycles are interconnected rather than operating independently.

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Clarification 2: Instruction includes feedback mechanisms that can amplify or moderate changes in element availability, including feedbacks altered by changes in the abundance or loss of organisms that regulate element movement.

Clarification 3: Instruction includes that changes in one cycle can influence other cycles across Earth systems.

Clarification 4: Instruction includes that feedbacks operate over different spatial and temporal scales.

Clarification 5: Instruction includes using systems models to represent interactions and feedback mechanisms among interconnected biogeochemical cycles. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.14.5 Analyze how scientific evidence is used to study the movement and transformation of elements within biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes using data from atmospheric measurements, water chemistry, soils, sediments, and biological tissues.

Clarification 2: Instruction includes isotope ratios and elemental concentrations as tools for tracing matter movement.

Clarification 3: Instruction includes that biogeochemical cycles are inferred from indirect evidence and scientific modeling.

Clarification 4: Instruction includes evaluating patterns and trends over time, including those inferred from fossil or sedimentary records associated with extinct organisms to understand cycle dynamics.

Clarification 5: Instruction includes analyzing quantitative data, isotope evidence, elemental concentrations, and long-term records to investigate the movement of matter through Earth systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes evaluating evidence from atmospheric measurements, water chemistry, soils, sediments, biological tissues, and other data sources to explain cycle dynamics. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.14.6 Synthesize how life depends on biogeochemical cycles and how living organisms modify these cycles over time.

Benchmark Clarifications:

Clarification 1: Instruction includes that life requires continuous availability of essential elements.

Clarification 2: Instruction includes how living organisms and ecosystem development influence biogeochemical cycle pathways and rates, and how changes in biological communities over time have modified these systems.

Clarification 3: Instruction includes that Earth's surface environments and biological communities are shaped by, and also influence, biogeochemical systems over time.

Clarification 4: Instruction includes using systems models to represent movement of matter among the atmosphere, hydrosphere, geosphere, and biosphere and the role of organisms in modifying cycle pathways and rates. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing biogeochemical data, isotope evidence, and long-term records to explain how living organisms influence biogeochemical cycles over time. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15 Evaluate how natural hazards arise from Earth system processes and how risk is assessed, monitored, and mitigated.

SC.912.PE.15.1 Analyze how natural hazards arise from interactions within Earth's systems.

Benchmark Clarifications:

Clarification 1: Instruction includes natural hazards: earthquakes, volcanic eruptions, tsunamis, hurricanes, floods, droughts, landslides, wildfires, and severe storms.

Clarification 2: Instruction includes internal Earth processes: mantle convection and plate tectonics.

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Clarification 3: Instruction includes surface and atmospheric processes: weather patterns, ocean circulation, and hydrologic cycling.

Clarification 4: Instruction includes that natural hazards can alter ecosystems and biological communities as a part of Earth system processes.

Clarification 5: Instruction includes using systems models to represent interactions among Earth's systems that generate natural hazards. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15.2 Analyze patterns in the global and regional distribution of natural hazards.

Benchmark Clarifications:

Clarification 1: Instruction includes the concentration of earthquakes and volcanoes along tectonic plate boundaries.

Clarification 2: Instruction includes the relationships between climate patterns and hazards such as hurricanes, droughts, floods, and wildfires.

Clarification 3: Instruction includes geographic factors: topography, coastal location, and watershed position.

Clarification 4: Instruction includes the use of maps and spatial data to identify hazard-prone regions.

Clarification 5: Instruction includes analyzing spatial patterns and relationships among tectonic features, climate zones, and hazard occurrence. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using maps and spatial models to represent regional and global patterns of natural hazards. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15.3 Evaluate how the frequency and magnitude of natural hazards influence their impacts.

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Benchmark Clarifications:

Clarification 1: Instruction includes differences between frequent, low-magnitude events and rare, high-magnitude events.

Clarification 2: Instruction includes spatial scale (local, regional and global) and temporal scale (short-term and long-term).

Clarification 3: Instruction includes that hazard impacts depend on both Earth processes and exposure of people, infrastructure, and biological communities.

Clarification 4: Instruction includes that historical records may include biological evidence, such as changes in species abundance or local extirpation following hazard events, and scientific data to evaluate hazard patterns over time.

Clarification 5: Instruction includes analyzing relationships among hazard frequency, magnitude, duration, and impacts across spatial and temporal scales. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical records and scientific data used to evaluate changes in hazard patterns over time. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15.4 Evaluate how scientists assess risk related to natural hazards.

Benchmark Clarifications:

Clarification 1: Instruction includes risk as a combination of hazard likelihood, exposure, and vulnerability.

Clarification 2: Instruction includes the use of hazard maps, probability models, and historical data.

Clarification 3: Instruction includes distinguishing between hazard (natural process) and risk (potential impact).

Clarification 4: Instruction includes that risk varies based on location, environmental conditions, and human presence.

Clarification 5: Instruction includes analyzing hazard likelihood, exposure, vulnerability, and risk using quantitative data and probability-based information. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using hazard maps, probability models, and risk models to evaluate natural hazard risk. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15.5 Analyze how natural hazards are monitored and how scientific data are used to provide warnings.

Benchmark Clarifications:

Clarification 1: Instruction includes tools such as seismographs, satellites, weather radar, ocean buoys, and GPS measurements.

Clarification 2: Instruction includes monitoring changes in Earth systems to detect conditions associated with hazards.

Clarification 3: Instruction includes that monitoring improves understanding and preparedness but does not prevent hazards.

Clarification 4: Instruction includes that predictions vary in certainty depending on the hazard type.

Clarification 5: Instruction includes analyzing monitoring data collected from Earth-observing technologies used to identify and track hazard conditions. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15.6 Evaluate how scientific understanding of Earth systems is used to reduce the impacts of natural hazards.

Benchmark Clarifications:

Clarification 1: Instruction includes mitigation strategies such as land-use planning, engineering design, and infrastructure adaptation.

Clarification 2: Instruction includes that hazard mitigation may be evaluated using evidence of system response, including changes in physical systems and biological recovery patterns.

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Clarification 3: Instruction includes that mitigation reduces risk but does not eliminate natural hazards.

Clarification 4: Instruction includes evaluating the effectiveness and limitations of different mitigation approaches.

Clarification 5: Instruction includes evaluating evidence used to assess the effectiveness of hazard mitigation strategies and system responses. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.15.7 Synthesize how interactions among Earth systems, human activity, and scientific monitoring influence hazard risk over time.

Benchmark Clarifications:

Clarification 1: Instruction includes that hazards often involve multiple interacting Earth systems.

Clarification 2: Instruction includes how changes in land use or climate patterns can influence hazard frequency or impact.

Clarification 3: Instruction includes integrating multiple data sources to explain hazard behavior and risk.

Clarification 4: Instruction includes that understanding natural hazards requires systems thinking, which may include examining how repeated hazards influence long-term ecosystem structure and species persistence, and scientific analysis.

Clarification 5: Instruction includes integrating spatial, temporal, and monitoring data to explain changes in hazard risk over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using systems models to represent interactions among Earth systems, human activities, monitoring efforts, and hazard risk. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes evaluating multiple sources of evidence used to explain hazard behavior and changes in risk over time. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.15.8 Analyze atmospheric conditions associated with severe weather events.

Benchmark Clarifications:

Clarification 1: Instruction includes thunderstorms, tornadoes, hurricanes, winter storms, severe weather forecasting, and severe weather monitoring.

SC.912.PE.15.9 Analyze atmospheric observations used to monitor and predict weather.

Benchmark Clarifications:

Clarification 1: Instruction includes temperature, air pressure, relative humidity, dew point, wind speed, wind direction, precipitation, weather stations, weather balloons, satellite systems, and radar systems.

SC.912.PE.15.10 Analyze atmospheric conditions and Earth system interactions associated with severe weather hazards affecting Florida.

Example: Analyze meteorological data, radar imagery, satellite observations, and forecast products associated with a Florida hurricane, severe thunderstorm outbreak, tornado event, or flooding event to explain how atmospheric and oceanic conditions contributed to the development, intensity, movement, and impacts of the hazard.

Benchmark Clarifications:

Clarification 1: Instruction includes hurricanes, tropical storms, thunderstorms, tornadoes, waterspouts, lightning, flooding, storm surge, and extreme precipitation events.

Clarification 2: Instruction includes atmospheric conditions associated with severe weather, including temperature, humidity, atmospheric stability, pressure systems, wind patterns, vertical air movement, and ocean-atmosphere interactions.

Clarification 3: Instruction includes the influence of sea-surface temperatures, the Gulf Stream, El Niño-Southern Oscillation (ENSO), and La Niña on severe weather patterns affecting Florida.

Clarification 4: Instruction includes relationships among thunderstorms, sea-breeze boundaries, lightning frequency, tornado development, and heavy rainfall events in Florida.

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Clarification 5: Instruction includes monitoring and forecasting severe weather using weather stations, weather balloons, radar systems, satellite observations, numerical weather models, and emergency warning systems.

Clarification 6: Instruction includes analyzing meteorological data to identify atmospheric conditions associated with severe weather formation, intensity, movement, and impacts. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes developing and using models to explain interactions among atmospheric conditions, ocean conditions, and severe weather hazards. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 8: Instruction includes analyzing observations, radar imagery, satellite data, forecast products, and historical storm records used to monitor and investigate severe weather hazards. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 9: Instruction includes examining historical Florida weather events and how scientific understanding of severe weather forecasting, preparedness, and hazard mitigation has changed as new evidence and technologies became available. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16 Evaluate how anthropogenic activities alter Earth systems, including climate, water resources, land surfaces, and biodiversity; and assess strategies for sustainability and resilience.

SC.912.PE.16.1 Analyze anthropogenic activities that interact with Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes anthropogenic activities: land-use change, resource extraction, agriculture, urbanization, energy production, and material consumption.

Clarification 2: Instruction includes that anthropogenic activities interact with the atmosphere, hydrosphere, geosphere, and biosphere, including the effects on habitats and species distributions.

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Clarification 3: Instruction includes distinguishing between natural Earth system processes and anthropogenic drivers.

Clarification 4: Instruction includes that anthropogenic influences vary in magnitude, extent, and duration.

Clarification 5: Instruction includes using systems models to represent interactions among anthropogenic activities and the atmosphere, hydrosphere, geosphere, and biosphere. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16.2 Evaluate evidence of how anthropogenic activities interact with atmospheric and energy-related Earth system processes.

Benchmark Clarifications:

Clarification 1: Instruction includes data related to atmospheric composition, Earth's energy balance, and heat transfer.

Clarification 2: Instruction includes evaluating temperature, precipitation, and large-scale circulation patterns using observational data and models.

Clarification 3: Instruction includes multiple interacting natural and anthropogenic factors influence atmospheric and Earth system processes.

Clarification 4: Instruction includes assessing uncertainty and variability in long-term atmospheric and energy-system data.

Clarification 5: Instruction includes analyzing long-term atmospheric, energy balance, temperature, and precipitation data to identify patterns, trends, variability, and uncertainty. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes evaluating observational data, monitoring records, and other scientific evidence used to investigate atmospheric and energy-related Earth system processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.PE.16.3 Evaluate how anthropogenic activities interact with Earth's water systems.

Example: Analyze nutrient and dissolved oxygen data from a freshwater lake experiencing eutrophication.

Benchmark Clarifications:

Clarification 1: Instruction includes surface water, groundwater, ice, and atmospheric water.

Clarification 2: Instruction includes anthropogenic activities: water withdrawal, land development, agriculture, and water management infrastructure.

Clarification 3: Instruction includes analyzing changes in water availability, quality, timing, movement, and regional variability in water-system response.

Clarification 4: Instruction includes that changes in water systems may be evaluated using physical measurements and biological indicators.

Clarification 5: Instruction includes evaluating anthropogenic impacts on estuarine, coastal, and marine environments including nutrient enrichment, harmful algal blooms, habitat degradation, sea-level rise, and changes in water quality.

Clarification 6: Instruction includes eutrophication resulting from nutrient enrichment and associated changes in dissolved oxygen, biological productivity, harmful algal blooms, fish mortality, and ecosystem structure. Clarification 7: Instruction includes analyzing water-system data and measurements to evaluate changes in water availability, movement, and quality. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 8: Instruction includes evaluating evidence from water-quality measurements, monitoring programs, biological indicators, and other scientific data sources. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16.4 Analyze how anthropogenic activities influence land surface processes.

Benchmark Clarifications:

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Clarification 1: Instruction includes changes to vegetation cover, soil properties, erosion patterns, and surface reflectivity.

Clarification 2: Instruction includes interactions among land surfaces, hydrologic processes, and atmospheric conditions.

Clarification 3: Instruction includes evaluating spatial patterns of land surface change using maps and imagery.

Clarification 4: Instruction includes distinguishing between short-term and long-term land surface changes.

Clarification 5: Instruction includes analyzing spatial patterns and rates of land surface change using maps, imagery, and other geospatial data. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using spatial, geologic, and Earth-system models to represent land surface change and its interactions with other Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16.5 Evaluate how anthropogenic activities are associated with changes in biodiversity and ecosystem structure.

Benchmark Clarifications:

Clarification 1: Instruction includes biodiversity at genetic, species, and ecosystem levels and may include threatened, endangered, extirpated, or extinct species as evidence of system change.

Clarification 2: Instruction includes that Earth system changes can alter habitat availability, nutrient cycling, and energy flow.

Clarification 3: Instruction includes analyzing patterns of biodiversity change using historical, modern, and fossil records across different regions and timescales.

Clarification 4: Instruction includes that biological responses vary across ecosystems and environmental conditions.

Clarification 5: Instruction includes marine biodiversity, coral reef ecosystems, seagrass communities, mangrove systems, and coastal habitats as examples of ecosystem-level biodiversity.

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Clarification 6: Instruction includes evaluating evidence from biodiversity records, ecological observations, population studies, and fossil records to investigate changes in ecosystem structure. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16.6 Analyze how anthropogenic activities influence biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes carbon, nitrogen, phosphorus, and hydrologic cycles.

Clarification 2: Instruction includes anthropogenic sources and transfer of matter within the carbon, nitrogen, phosphorus, and hydrologic cycles.

Clarification 3: Instruction includes evaluating how changes in cycling rates or reservoirs may be associated with changes in organism populations, including loss or reduction of key species.

Clarification 4: Instruction includes that biogeochemical cycle responses can involve feedbacks and interactions among Earth systems.

Clarification 5: Instruction includes analyzing changes in cycle reservoirs, transfer pathways, and cycling rates using quantitative data. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using systems models to represent anthropogenic influences on biogeochemical cycles and interactions among Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16.7 Evaluate strategies related to sustainability and resilience using Earth system evidence.

Benchmark Clarifications:

Clarification 1: Instruction includes sustainability as maintaining Earth system functions over time and resilience as the capacity to respond to change.

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Clarification 2: Instruction includes analyzing scientific data, such as physical measurements, ecological indicators, and population trends, to evaluate different strategies or approaches.

Clarification 3: Instruction includes that strategies are assessed based on evidence of system response rather than intended outcomes.

Clarification 4: Instruction includes recognizing trade-offs, limitations, and uncertainties in evaluating Earth system responses.

Clarification 5: Instruction includes evidence-based conservation and restoration strategies such as habitat restoration, marine protected areas, fisheries management, coral restoration, and coastal resilience planning.

Clarification 6: Instruction includes analyzing scientific data and system indicators to compare outcomes associated with sustainability and resilience strategies. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes evaluating evidence from physical, ecological, and Earth-system measurements used to assess sustainability and resilience strategies. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.16.8 Evaluate how scientific knowledge and technology are used to conserve, restore, and sustain marine and coastal ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes fisheries management, habitat restoration coral restoration, and marine protected areas.

Clarification 2: Instruction includes evaluating impacts of pollution, nutrient enrichment, habitat loss, invasive species, and climate-related stressors.

Clarification 3: Instruction includes analyzing environmental monitoring data used to guide conservation and restoration decisions.

Clarification 4: Instruction includes evaluating tradeoffs among ecological, economic, and societal considerations associated with marine resource management.

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Clarification 5: Instruction includes developing and using systems models to evaluate conservation and restoration strategies. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.PE.17 Analyze marine systems through the interpretation of oceanographic data, development and evaluation of models, spatial analysis, scientific investigation, and evidence-based explanations to understand interactions among physical, chemical, geological, biological, and climatic processes within the world's oceans.

SC.912.PE.17.1 Analyze oceanographic datasets to explain relationships among physical, chemical, geological, and biological processes within marine systems.

Benchmark Clarifications:

Clarification 1: Instruction includes salinity, temperature, density, dissolved oxygen, nutrients, pH, chlorophyll concentration, and ocean circulation data.

Clarification 2: Instruction includes identifying patterns, trends, correlations, and anomalies using marine datasets.

Clarification 3: Instruction includes evaluating relationships among oceanographic variables and marine environmental conditions.

SC.912.PE.17.2 Develop, evaluate, and refine models that explain interactions among ocean circulation, climate, marine productivity, biodiversity, and ecosystem stability.

Benchmark Clarifications:

Clarification 1: Instruction includes interactions among atmospheric circulation, ocean circulation, nutrient transport, and biological productivity.

Clarification 2: Instruction includes evaluating model assumptions, limitations, and predictive capabilities.

Clarification 3: Instruction includes comparing multiple models used to explain marine phenomena.

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SC.912.PE.17.3 Analyze spatial patterns within marine environments using maps, geospatial datasets, bathymetric data, and remote-sensing technologies.

Benchmark Clarifications:

Clarification 1: Instruction includes bathymetric maps, habitat maps, ocean circulation maps, and satellite imagery.

Clarification 2: Instruction includes relationships among seafloor features, ocean circulation, biodiversity, and productivity.

Clarification 3: Instruction includes evaluating spatial variability among coastal, estuarine, reef, pelagic, and deep-ocean environments.

Clarification 4: Instruction includes littoral, intertidal, subtidal, neritic, pelagic, benthic, and deep-ocean zones and the environmental gradients that characterize each zone.

Clarification 5: Instruction includes relationships among substrate characteristics such as sand, mud, rock, shell, and coral and the distribution of marine organisms and biological communities.

Clarification 6: Instruction includes littoral, intertidal, subtidal, neritic, pelagic, benthic, and abyssal zones and the environmental conditions and organisms associated with each zone.

SC.912.PE.17.4 Evaluate scientific explanations of marine phenomena using multiple sources of evidence and quantitative data.

Benchmark Clarifications:

Clarification 1: Instruction includes oceanographic, ecological, geological, chemical, and climatological evidence.

Clarification 2: Instruction includes distinguishing among observations, inferences, interpretations, and conclusions.

Clarification 3: Instruction includes evaluating uncertainty, reliability, and limitations associated with scientific evidence.

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SC.912.PE.17.5 Design, evaluate, and communicate investigations used to answer scientific questions about marine systems.

Benchmark Clarifications:

Clarification 1: Instruction includes hypothesis development, variable identification, experimental design, field investigations, and data collection.

Clarification 2: Instruction includes evaluating investigations based on reliability, validity, precision, accuracy and sources of uncertainty.

SC.912.PE.18 Analyze the diversity of marine life, interactions among marine organisms and ecosystems, and the biological, ecological, and human factors that influence the structure, function, sustainability, and resilience of marine systems.

SC.912.PE.18.1 Analyze how evolutionary processes contribute to the diversity, adaptation, and distribution of marine organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes natural selection, adaptation, speciation, extinction, and common ancestry.

Clarification 2: Instruction includes structural, physiological, and behavioral adaptations of marine organisms.

Clarification 3: Instruction includes relationships among environmental conditions, adaptation, and organism distribution.

Clarification 4: Instruction includes evidence from fossils, comparative anatomy, genetics, and phylogenetic relationships.

SC.912.PE.18.2 Analyze factors that influence marine biodiversity and the distribution of organisms within marine ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes temperature, salinity, dissolved oxygen, nutrient availability, pressure, light availability, and habitat structure.

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Clarification 2: Instruction includes coastal, estuarine, reef, pelagic, benthic, and deep-ocean environments.

Clarification 3: Instruction includes relationships among biodiversity, environmental conditions, and ecosystem stability.

Clarification 4: Instruction includes estuaries as highly productive transition zones that support biodiversity, nutrient cycling, nursery habitats, and connectivity between freshwater and marine environments.

SC.912.PE.18.3 Analyze the movement of energy and cycling of matter within marine ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes primary productivity, food webs, food chains, trophic interactions, and nutrient cycling.

Clarification 2: Instruction includes phytoplankton, zooplankton, marine producers, consumers, decomposers, and detrital pathways.

Clarification 3: Instruction includes relationships among productivity, biodiversity, and ecosystem structure.

Clarification 4: Instruction includes biological, chemical, and physical processes that cycle matter and transfer energy.

Clarification 5: Instruction includes phytoplankton and macroalgae as primary producers, sources of dissolved oxygen, prey resources, habitat-forming organisms, and symbiotic partners within marine ecosystems.

SC.912.PE.18.4 Evaluate interactions among organisms within marine ecosystems and how those interactions influence ecosystem structure and function.

Benchmark Clarifications:

Clarification 1: Instruction includes competition, predation, herbivory, mutualism, commensalism, parasitism, and symbiosis.

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Clarification 2: Instruction includes keystone species, ecosystem engineers, and ecological niches.

Clarification 3: Instruction includes relationships among species interactions, biodiversity, and ecosystem stability.

Clarification 4: Instruction includes ecological relationships involving planktonic algae, macroalgae, corals, fungi, microorganisms, and consumer populations.

SC.912.PE.18.5 Evaluate how disturbances and environmental changes influence marine ecosystems and ecological resilience.

Benchmark Clarifications:

Clarification 1: Instruction includes natural disturbances such as storms, disease outbreaks, and environmental variability.

Clarification 2: Instruction includes anthropogenic disturbances such as pollution, habitat loss, harmful algal blooms, invasive species, overharvesting, and climate-related impacts.

Clarification 3: Instruction includes ecosystem resistance, recovery, resilience, and thresholds of change.

SC.912.PE.18.6 Analyze how humans use marine resources and evaluate strategies that promote sustainability and conservation.

Benchmark Clarifications:

Clarification 1: Instruction includes fisheries, aquaculture, recreation, transportation, mineral resources, and ecosystem services.

Clarification 2: Instruction includes habitat restoration, marine protected areas, fisheries management, and conservation planning.

Clarification 3: Instruction includes ecological, economic, and societal considerations associated with marine resource management.

Clarification 4: Instruction includes evidence-based decision making and environmental stewardship.

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Proposed DRAFT Standards

SC.912.PE.19 Evaluate marine systems through scientific investigations, quantitative analyses, systems modeling, and evidence-based reasoning to explain ecological patterns, environmental change, and marine resource management.

SC.912.PE.19.1 Evaluate scientific evidence used to explain patterns of marine biodiversity, adaptation, and ecosystem change.

Benchmark Clarifications:

Clarification 1: Instruction includes fossil, genetic, ecological, and environmental evidence.

Clarification 2: Instruction includes evaluating strengths, limitations, reliability, and uncertainty associated with scientific evidence.

Clarification 3: Instruction includes comparing competing scientific explanations.

SC.912.PE.19.2 Develop, evaluate, and refine models that explain relationships among biodiversity, productivity, environmental change, and ecosystem resilience within marine systems.

Benchmark Clarifications:

Clarification 1: Instruction includes systems models, conceptual models, and quantitative models.

Clarification 2: Instruction includes feedback mechanisms, thresholds, resilience, and system responses.

Clarification 3: Instruction includes evaluating assumptions and limitations associated with models.

SC.912.PE.19.3 Analyze quantitative marine datasets to investigate ecological relationships and environmental change.

Benchmark Clarifications:

Clarification 1: Instruction includes population data, biodiversity indices, productivity measurements, fisheries datasets, climate data, and water-quality records.

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Clarification 2: Instruction includes identifying trends, patterns, correlations, anomalies, and rates of change.

Clarification 3: Instruction includes interpreting graphical, tabular, spatial, and temporal representations of data.

SC.912.PE.19.4 Design and evaluate investigations used to answer scientific questions about marine organisms, ecosystems, and environmental processes.

Benchmark Clarifications:

Clarification 1: Instruction includes hypothesis development, experimental design, variable identification, sampling methods, and data collection.

Clarification 2: Instruction includes evaluating investigations for reliability, validity, precision, accuracy, and sources of uncertainty.

Clarification 3: Instruction includes field investigations, laboratory investigations, and analysis of existing datasets.

SC.912.PE.19.5 Develop and communicate evidence-based arguments regarding marine environmental issues, conservation strategies, and resource-management decisions.

Benchmark Clarifications:

Clarification 1: Instruction includes evaluating multiple sources of scientific evidence.

Clarification 2: Instruction includes ecological, economic, and societal considerations.

Clarification 3: Instruction includes communicating scientific explanations using quantitative evidence, models, data visualizations, and scientific reasoning.

The Science of Space

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Proposed DRAFT Standards

How the universe is organized, progresses, and is investigated through gravity, energy, matter, light, and human exploration.

Grades 9-12

SC.912.SP.1 Analyze how Earth is part of a larger cosmic system that includes the Solar System, the Milky Way galaxy, and the observable universe.

SC.912.SP.1.1 Analyze Earth’s position and motion within the Solar System.

Benchmark Clarifications:

Clarification 1: Instruction includes Earth’s orbit around the Sun and rotation on its axis.

Clarification 2: Instruction includes gravitational relationships among the Sun, Earth, and Moon.

Clarification 3: Instruction includes Earth as one system interacting within the larger Solar System.

Clarification 4: Instruction includes using models to represent Earth's position, motion, and interactions within the Solar System. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.1.2 Analyze Earth’s location within the Milky Way galaxy and the observable universe.

Benchmark Clarifications:

Clarification 1: Instruction includes the Milky Way as a spiral galaxy containing billions of stars and planetary systems.

Clarification 2: Instruction includes the Sun’s position within the Milky Way galaxy.

Clarification 3: Instruction includes the observable universe as the region detectable through electromagnetic radiation.

Clarification 4: Instruction includes hierarchical organization within the universe including Earth, the Solar System, the Milky Way galaxy, and the observable universe.

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Clarification 5: Instruction includes using scale models and system models to represent Earth's location within larger cosmic structures. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.1.3 Analyze how interactions across cosmic scales influence Earth's environment and conditions for life.

Example: Examine how seagrass beds in Florida's coastal waters, such as those in Florida Bay or the Indian River Lagoon, depend on conditions set by larger cosmic systems, including consistent solar radiation that drives photosynthesis and Earth's stable orbit that maintains seasonal climate patterns. Explain how solar energy supports seagrass growth, how gravitational interactions help regulate tides and long-term environmental stability, and how cosmic events such as changes in solar activity could affect seagrass health and the living organisms that depend on these habitats.

Benchmark Clarifications:

Clarification 1: Instruction includes solar radiation as Earth's primary external energy source.

Clarification 2: Instruction includes gravitational interactions among the Sun, Earth, and Moon that contribute to orbital stability and influence Earth systems.

Clarification 3: Instruction includes cosmic events with potential Earth impacts.

Clarification 4: Instruction includes Earth's dependence on conditions set by larger cosmic systems.

Clarification 5: Instruction includes using systems models to represent connections among solar energy, gravitational interactions, Earth systems, and conditions that support life. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing observations and scientific evidence used to explain how cosmic interactions affect Earth systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.SP.2 Analyze how gravitational interactions govern the motion of planets, moons, asteroids, comets, and human-made satellites.

SC.912.SP.2.1 Analyze how gravity governs orbital motion in space systems.

Benchmark Clarifications:

Clarification 1: Instruction includes gravitational attraction between masses.

Clarification 2: Instruction includes the relationship between gravitational force, distance, and mass.

Clarification 3: Instruction includes stable and changing orbital paths.

Clarification 4: Instruction includes analyzing relationships among mass, distance, gravitational force, and orbital motion. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using models to represent gravitational interactions and orbital motion within space systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to gravitational theory and the scientific understanding of orbital motion. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.2.2 Analyze gravitational interactions involving natural and artificial objects.

Benchmark Clarifications:

Clarification 1: Instruction includes planetary and lunar orbits.

Clarification 2: Instruction includes asteroid and comet trajectories.

Clarification 3: Instruction includes artificial satellites and space debris interacting through gravity.

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Clarification 4: Instruction includes using models to represent gravitational interactions among planets, moons, asteroids, comets, satellites, and other objects in space. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing observational data used to investigate the motion of natural and artificial objects in space. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.2.3 Analyze how gravitational interactions involve exchanges between kinetic and potential energy in orbital systems.

Example: Analyze the orbit of an Earth-orbiting satellite to explain how the Moon's gravitational pull perturbs the satellite's path, causing ongoing exchanges between kinetic energy and gravitational potential energy. Using diagrams or scenario data, explain how the Moon's gravity alters orbital shape and distance over time, leading to non-circular, perturbed orbits that require energy adjustments to maintain satellite stability.

Benchmark Clarifications:

Clarification 1: Instruction includes kinetic and gravitational potential energy in orbits.

Clarification 2: Instruction includes changes in energy with orbital shape and distance.

Clarification 3: Instruction includes non-circular and perturbed orbits.

Clarification 4: Instruction includes analyzing relationships among orbital distance, orbital speed, kinetic energy, and gravitational potential energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using orbital models and diagrams to represent energy changes in circular, elliptical, and perturbed orbits. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing observational and simulated data used to explain changes in orbital motion and energy within gravitational systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.SP.3 Analyze how the Solar System formed and how physical properties distinguish planets, moons, asteroids, and comets.

SC.912.SP.3.1 Analyze scientific models explaining the formation of the Solar System.

Example: Examine multiple scientific models used to explain the formation of the Solar System and analyze how each model represents processes such as disk formation, accretion, and planetary motion. Explain how scientists use models to test ideas against evidence such as orbital patterns and compositional differences among planets and revise models over time as new observations and data become available.

Benchmark Clarifications:

Clarification 1: Instruction includes scientific models describing the formation of the Solar System from a rotating cloud of gas and dust.

Clarification 2: Instruction includes gravitational collapse, disk formation, and accretion as processes involved in Solar System formation.

Clarification 3: Instruction includes formation of planets, moons, asteroids, and comets from material within the protoplanetary disk.

Clarification 4: Instruction includes evidence supporting scientific models of Solar System formation such as orbital patterns, planetary composition, and distribution of Solar System objects.

Clarification 5: Instruction includes using physical, conceptual, and computational models to represent the formation and evolution of the Solar System. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to scientific explanations of Solar System formation and how models have changed as new evidence became available. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.3.2 Analyze physical properties that distinguish Solar System objects.

Benchmark Clarifications:

Clarification 1: Instruction includes composition, size, density, and location.

Clarification 2: Instruction includes rocky terrestrial planets: Mercury, Venus, Earth, and Mars.

Clarification 3: Instruction includes gas and ice giants: Jupiter, Saturn, Uranus, and Neptune.

Clarification 4: Instruction includes moons, asteroids, and comets as distinct object classes.

Clarification 5: Instruction includes comparative composition trends between inner and outer Solar System objects.

Clarification 6: Instruction includes analyzing relationships among composition, density, size, location, and other physical properties used to distinguish Solar System objects. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.4 Analyze how electromagnetic radiation is produced, transmitted, and detected to investigate objects and processes in space.

SC.912.SP.4.1 Analyze how electromagnetic radiation carries information through space.

Benchmark Clarifications:

Clarification 1: Instruction includes the electromagnetic spectrum.

Clarification 2: Instruction includes radiation emission from stars and other cosmic objects.

Clarification 3: Instruction includes transmission of energy through space without matter.

Clarification 4: Instruction includes wavelength, frequency, and energy as properties used to distinguish regions of the electromagnetic spectrum.

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Clarification 5: Instruction includes analyzing relationships among wavelength, frequency, and energy across the electromagnetic spectrum. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using models to represent how electromagnetic radiation is produced, transmitted, and used to acquire information about objects in space. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.4.2 Analyze how detectors and instruments use electromagnetic radiation to study space.

Benchmark Clarifications:

Clarification 1: Instruction includes telescopes sensitive to different wavelengths.

Clarification 2: Instruction includes spectroscopic data revealing composition and motion.

Clarification 3: Instruction includes remote sensing as a primary tool of astronomy.

Clarification 4: Instruction includes using spectra, images, and other observational data to identify properties of astronomical objects including composition, temperature, and motion. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes analyzing observations and data collected by telescopes, detectors, and other astronomical instruments to investigate objects and processes in space. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to telescopes, spectroscopy, and remote sensing technologies used in astronomy. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.5 Analyze the structure, energy production, and life cycles of stars and how stellar processes influence surrounding space environments.

SC.912.SP.5.1 Analyze how stars produce energy and maintain structural stability.

Benchmark Clarifications:

Clarification 1: Instruction includes nuclear fusion in stellar cores.

Clarification 2: Instruction includes energy release through mass-energy conversion.

Clarification 3: Instruction includes balance between gravitational collapse and outward pressure.

Clarification 4: Instruction includes that hydrogen fusion forms helium and releases energy that powers stars.

Clarification 5: Instruction includes using models to represent energy production and structural stability within stars. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to nuclear fusion, stellar structure, and the scientific understanding of how stars produce energy. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.5.2 Analyze stages of stellar life cycles and their environmental effects.

Benchmark Clarifications:

Clarification 1: Instruction includes stellar life cycles from formation through end states.

Clarification 2: Instruction includes supernovae, planetary nebulae, and stellar remnants.

Clarification 3: Instruction includes enrichment of surrounding space with heavy elements.

Clarification 4: Instruction includes that stellar evolution depends primarily on stellar mass.

Clarification 5: Instruction includes using models to represent stages of stellar evolution and the relationships among stellar mass, lifetime, and end state. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to stellar classification, stellar evolution, and the origin of heavy elements. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.SP.5.3 Analyze how energy emitted by stars influences surrounding space environments.

Benchmark Clarifications:

Clarification 1: Instruction includes stellar radiation and particle emissions.

Clarification 2: Instruction includes effects on surrounding gas, dust, and planetary systems.

Clarification 3: Instruction includes stellar winds and radiation pressure.

Clarification 4: Instruction includes star-environment interactions over time.

Clarification 5: Instruction includes using models to represent interactions among stellar radiation, stellar winds, surrounding matter, and planetary systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing observational evidence used to investigate the effects of stars on surrounding space environments. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.6 Analyze patterns in the structure and distribution of galaxies and matter across the universe.

SC.912.SP.6.1 Analyze large-scale patterns in galaxy structure and distribution.

Benchmark Clarifications:

Clarification 1: Instruction includes spiral, elliptical, and irregular galaxies.

Clarification 2: Instruction includes galaxy clusters, filaments, and voids.

Clarification 3: Instruction includes non-uniform distribution of matter in the universe.

Clarification 4: Instruction includes observational evidence for unseen matter influencing galactic motion and large-scale gravitational behavior.

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Clarification 5: Instruction includes using models and large-scale maps to represent galaxy distributions, clusters, filaments, and voids. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to galaxy classification, galaxy surveys, and scientific understanding of large-scale structure in the universe. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.6.2 Analyze how astronomical evidence is used to identify and map the large-scale distribution of matter in the universe.

Example: Examine the mock dataset below of galaxy redshift measurements collected from a sky survey and use the data to infer how matter is distributed across large scales in the universe. Using redshift as evidence of galaxy distance and motion, explain how scientists identify clusters, filaments, and voids through indirect observations rather than direct measurement of matter.

Mock Galaxy Redshift Dataset | Galaxy Survey Sample

Galaxy ID	Observed Redshift (z)	Approximate Distance (million light-years)	Relative Motion
G-101	0.005	70	Moving away slowly
G-102	0.006	85	Moving away slowly
G-103	0.007	100	Moving away
G-201	0.020	280	Moving away faster
G-202	0.021	295	Moving away faster
G-301	0.045	620	Moving away very fast
G-401	0.080	1,100	Moving away extremely fast

Note: Increasing redshift values correspond to increasing distance and recessional velocity due to cosmic expansion.

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Benchmark Clarifications:

Clarification 1: Instruction includes observational data from galaxy surveys and sky maps.

Clarification 2: Instruction includes measurements of galaxy positions, distances, and motions.

Clarification 3: Instruction includes the use of redshift data to infer large-scale structure.

Clarification 4: Instruction includes that distribution patterns are inferred from indirect observations rather than direct measurement of matter.

Clarification 5: Instruction includes analyzing relationships among redshift, distance, and galaxy motion to interpret large-scale patterns in the universe. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes using maps, simulations, and other scientific models to represent the large-scale distribution of matter in the universe. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes evaluating observational evidence from galaxy surveys, sky maps, and redshift measurements used to infer the distribution of matter in the universe. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.SP.7 Analyze how scientists use light-travel time, astronomical evidence, and models to interpret the history and expansion of the universe.

SC.912.SP.7.1 Analyze how light-travel time provides evidence of cosmic history.

Benchmark Clarifications:

Clarification 1: Instruction includes that distant objects are observed as they existed in the past.

Clarification 2: Instruction includes increasing look-back time with distance.

Clarification 3: Instruction includes limits of observation imposed by the speed of light.

Clarification 4: Instruction includes analyzing relationships among distance, light-travel time, and observations of cosmic history. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using models and visual representations to explain look-back time and observations of distant objects. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to the speed of light and scientific understanding of cosmic distance and history. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.7.2 Analyze evidence supporting an expanding universe.

Benchmark Clarifications:

Clarification 1: Instruction includes redshift of distant galaxies.

Clarification 2: Instruction includes cosmic background radiation as evidence used to investigate the history and expansion of the universe.

Clarification 3: Instruction includes the use of models to explain expansion patterns.

Clarification 4: Instruction includes analyzing relationships among redshift, galaxy distance, and expansion of the universe. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes evaluating evidence from redshift measurements, galaxy surveys, and background radiation observations used to support scientific explanations of an expanding universe. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to galaxy redshift, cosmic expansion, and background radiation evidence. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.7.3 Analyze the role of scientific uncertainty and model limitations in interpreting the history of the universe.

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Benchmark Clarifications:

Clarification 1: Instruction includes limits of observation due to distance and time.

Clarification 2: Instruction includes reliance on indirect evidence.

Clarification 3: Instruction includes refinement of models as new data emerge.

Clarification 4: Instruction includes distinguishing observation from interpretation.

Clarification 5: Instruction includes evaluating strengths and limitations of scientific models used to explain the history and evolution of the universe. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes evaluating multiple lines of observational evidence used to develop and revise scientific explanations of the universe. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.8 Evaluate how solar activity, radiation, and near-Earth space phenomena interact with Earth systems and influence natural and human-made systems.

SC.912.SP.8.1 Evaluate interactions between solar activity and Earth systems.

Benchmark Clarifications:

Clarification 1: Instruction includes solar flares and coronal mass ejections.

Clarification 2: Instruction includes Earth’s magnetosphere and atmosphere.

Clarification 3: Instruction includes energy transfer from the Sun to Earth systems.

Clarification 4: Instruction includes cosmic radiation and its interactions with Earth's atmosphere and magnetosphere.

Clarification 5: Instruction includes using models to represent interactions among solar activity, the magnetosphere, atmosphere, and Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing observations and monitoring data used to investigate solar activity and its effects on Earth systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 7: Instruction includes examining historical developments related to solar activity, geomagnetic storms, and scientific understanding of space weather. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.8.2 Evaluate risks and impacts from near-Earth space phenomena.

Benchmark Clarifications:

Clarification 1: Instruction includes asteroids and comets with Earth-crossing orbits.

Clarification 2: Instruction includes atmospheric and surface impacts.

Clarification 3: Instruction includes monitoring and mitigation strategies.

Clarification 4: Instruction includes evaluating relationships among object size, velocity, impact energy, and potential consequences. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes using orbital models and impact models to evaluate potential interactions between near-Earth objects and Earth. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes analyzing observational data used to identify, track, and assess near-Earth objects and impact risk. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes examining historical impact events and their role in shaping scientific understanding of impact hazards and mitigation strategies. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.8.3 Analyze radiation in space environments and evaluate strategies that reduce radiation exposure to living systems and technology.

Example: Evaluate radiation hazards associated with long-duration space missions.

Example: Analyze the protective role of Earth’s magnetic field.

Benchmark Clarifications:

Clarification 1: Instruction includes galactic cosmic rays, solar energetic particles, and electromagnetic radiation produced by the Sun.

Clarification 2: Instruction includes the role of Earth's atmosphere and magnetosphere in reducing radiation exposure.

Clarification 3: Instruction includes radiation effects on spacecraft systems, electronics, and living organisms.

Clarification 4: Instruction includes evaluating factors that influence radiation exposure in space environments, including altitude, orbital location, mission duration, and solar activity.

Clarification 5: Instruction includes evaluating shielding, spacecraft design, operational procedures, and other strategies used to reduce radiation exposure.

Clarification 6: Instruction includes interpreting radiation data and observations to evaluate radiation hazards in Earth and space environments. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes using models to represent interactions among solar activity, radiation, Earth's atmosphere, Earth's magnetosphere, and space-based systems. Refer to Modeling Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 8: Instruction includes examining historical developments that contributed to scientific understanding of cosmic radiation, space weather, and radiation protection in space exploration. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.9 Analyze how scientists use telescopes, spacecraft, simulations, and data analysis to investigate space phenomena.

SC.912.SP.9.1 Analyze observational and experimental tools used in space science.

Example: Case Study – The Artemis Program, launched from Florida’s Space Coast at Kennedy Space Center, uses advanced spacecraft and probes to study the Moon and prepare for future human missions deeper into space. Artemis missions collect data on the Moon’s surface, radiation environment, and available resources, such as water ice, to test technologies and living systems needed for long-duration exploration. These missions also

serve as a stepping-stone for future human missions to Mars, where similar spacecraft, life-support systems, and propulsion technologies will be required. Data transmitted from Artemis spacecraft are processed and analyzed to improve understanding of planetary environments and guide the design of safe and sustainable Mars missions.

Student Task(s) –

- Analyze how spacecraft and probes used in the Artemis program collect data that support both lunar exploration and future missions to Mars.
- Explain how data from Florida-launched Artemis missions help scientists prepare for the challenges of human exploration beyond the Moon.

Benchmark Clarifications:

Clarification 1: Instruction includes ground-based and space-based telescopes.

Clarification 2: Instruction includes spacecraft missions and probes.

Clarification 3: Instruction includes data collection and processing techniques.

Clarification 4: Instruction includes observations collected across multiple wavelengths and through multiple types of scientific instruments.

Clarification 5: Instruction includes evaluating data collected by telescopes, spacecraft, probes, and other scientific instruments used to investigate space phenomena. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to telescopes, spacecraft, robotic exploration, and major space science missions. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.9.2 Analyze how models and simulations support space science investigations.

Benchmark Clarifications:

Clarification 1: Instruction includes computational and physical models.

Clarification 2: Instruction includes testing hypotheses under varying conditions.

Clarification 3: Instruction includes model refinement based on new evidence.

Clarification 4: Instruction includes using models and simulations to investigate phenomena that cannot be directly observed or experimentally reproduced.

Clarification 5: Instruction includes evaluating strengths and limitations of scientific models and simulations used in space science investigations.

Clarification 6: Instruction includes analyzing outputs from scientific simulations and models to support explanations of space phenomena. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 7: Instruction includes examining historical developments related to the use of scientific models and computer simulations in astronomy and space exploration. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.10 Evaluate how space exploration and satellite technologies interact with Earth-space systems and contribute to scientific understanding and applications.

SC.912.SP.10.1 Evaluate how satellites contribute to Earth-space system understanding.

Benchmark Clarifications:

Clarification 1: Instruction includes monitoring Earth systems from space.

Clarification 2: Instruction includes communication, navigation, and weather observation.

Clarification 3: Instruction includes feedback between Earth observations and space science.

Clarification 4: Instruction includes Earth observation data used to investigate atmospheric, oceanic, geologic, and environmental processes.

Clarification 5: Instruction includes evaluating data collected from satellite observations to support scientific understanding of Earth-space systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Clarification 6: Instruction includes examining historical developments related to satellites, Earth observation programs, navigation systems, and space-based communication technologies. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

SC.912.SP.10.2 Evaluate the benefits and challenges of space exploration technologies.

Example: Evaluate the benefits and challenges of space exploration technologies associated with Florida's Space Coast, such as launches from Cape Canaveral, satellite deployment, and human spaceflight programs. Consider the scientific and economic benefits alongside energy demands, safety risks, and environmental impacts to explain how space technologies influence long-term sustainability, workforce development, and community growth in Florida.

Benchmark Clarifications:

Clarification 1: Instruction includes scientific, technological, and societal benefits.

Clarification 2: Instruction includes energy, safety, and sustainability constraints.

Clarification 3: Instruction includes long-term scientific, societal, and environmental impacts of space exploration.

Clarification 4: Instruction includes analyzing costs, resource requirements, risk factors, and potential benefits associated with space exploration technologies. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 5: Instruction includes evaluating evidence used to assess scientific, technological, economic, environmental, and societal impacts of space exploration technologies. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes examining historical developments related to human spaceflight, robotic exploration, and space technology innovation. Refer to Timeline of Key Accomplishments Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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SC.912.SP.10.3 Evaluate trade-offs involved in long-term space exploration and satellite use.

Benchmark Clarifications:

Clarification 1: Instruction includes cost, resource use, and environmental impact.

Clarification 2: Instruction includes technological benefits and limitations.

Clarification 3: Instruction includes societal priorities and workforce implications.

Clarification 4: Instruction includes that decisions regarding space exploration and satellite technologies often involve balancing scientific goals, societal needs, environmental considerations, and available resources.

Clarification 5: Instruction includes comparing costs, benefits, risks, and resource requirements associated with alternative approaches to space exploration and satellite operations. Refer to Mathematics Skills Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

Clarification 6: Instruction includes evaluating scientific evidence and data used to support decisions related to long-term space exploration and satellite use. Refer to Laboratory Practices Supporting Mastery of 9-12 Planet Earth and Space Benchmarks.

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Proposed DRAFT Standards

The Science of Life

Where life exists, how living systems are organized, how organisms interact, and how biodiversity is classified and sustained.

Grades 9-12

SC.912.SL.1 Describe and analyze evidence to explain how living organisms are classified into domains, kingdoms, and major groups based on shared structural, functional, and ecological characteristics; and how classification systems help organize and interpret biological diversity.

SC.912.SL.1.1 Describe the purpose of biological classification and summarize how classification systems are used to organize biological diversity.

Benchmark Clarifications:

Clarification 1: Instruction includes classification as a systematic method for organizing information about living organisms.

Clarification 2: Instruction includes how classification supports identification, comparison, and communication among scientists.

Clarification 3: Instruction includes recognizing classification as a tool for identifying patterns of similarity and difference.

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Clarification 4: Instruction includes that classification systems are revised as scientific knowledge advances.

Clarification 5: Instruction includes examining historical developments related to biological classification and how scientific classification systems have changed as new observations, technologies, and scientific evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.1.2 Differentiate among domains and kingdoms by classifying organisms based on shared cellular and molecular characteristics.

Benchmark Clarifications:

Clarification 1: Instruction includes the three domains: Bacteria, Archaea, and Eukarya.

Clarification 2: Instruction includes characteristics such as cell type, cellular organization, and genetic material.

Clarification 3: Instruction includes major kingdoms within Eukarya.

Clarification 4: Instruction includes comparing similarities and differences among domains and kingdoms.

Clarification 5: Instruction includes the use of molecular evidence, including similarities and differences in genetic information, to distinguish domains and kingdoms.

Clarification 6: Instruction includes using molecular models and representations to compare cellular and genetic characteristics among domains and kingdoms. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes analyzing cellular and molecular evidence used to classify organisms into domains and kingdoms. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.1.3 Analyze how shared structural and functional characteristics are used to group organisms into major biological categories.

Benchmark Clarifications:

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Clarification 1: Instruction includes cellular features such as cell walls, organelles, and organization.

Clarification 2: Instruction includes functional traits such as metabolism, reproduction, and nutrition.

Clarification 3: Instruction includes that classification is based on multiple characteristics rather than isolated traits.

Clarification 4: Instruction includes using observable and measurable characteristics as classification evidence.

Clarification 5: Instruction includes analyzing observations and evidence used to classify organisms based on shared structural and functional characteristics. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.1.4 Examine how ecological roles and environmental interactions contribute to the classification of living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes ecological roles: producers, consumers, and decomposers.

Clarification 2: Instruction includes habitat use and interactions with biotic and abiotic factors.

Clarification 3: Instruction includes how ecological traits and environmental interactions contribute to distinguishing major organismal groups.

Clarification 4: Instruction includes recognizing ecology as complementary to structural and functional evidence.

Clarification 5: Instruction includes comparing organism distributions, habitat use, and ecological roles across environments to identify biological patterns. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.1.5 Analyze how classification systems are used to interpret patterns of biological diversity across organisms and environments.

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Benchmark Clarifications:

Clarification 1: Instruction includes identifying relationships among organisms using classification frameworks.

Clarification 2: Instruction includes comparing biological diversity within and across major groups.

Clarification 3: Instruction includes using classification to support comparative biological studies.

Clarification 4: Instruction includes recognizing variation in biological diversity across environments and scales.

Clarification 5: Instruction includes recognizing that molecular evidence has improved scientists' ability to identify relationships among organisms and interpret biological diversity.

Clarification 6: Instruction includes analyzing biodiversity, geographic distribution, environmental data to identify patterns of similarity, difference, distribution, and diversity among organisms and ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.1.6 Evaluate how scientific evidence supports the development and revision of biological classification systems.

Benchmark Clarifications:

Clarification 1: Instruction includes structural, functional, and molecular evidence.

Clarification 2: Instruction includes that classification systems change with new evidence.

Clarification 3: Instruction includes peer review and scientific consensus.

Clarification 4: Instruction includes distinguishing scientific classification from common naming systems.

Clarification 5: Instruction includes evaluating and refining classification models using structural, molecular, and ecological evidence. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes analyzing molecular evidence, including DNA and other biochemical data, used to support and revise biological classification systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to biological classification and how scientific explanations of relationships among organisms have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.2 Analyze how living organisms are distributed across Earth's habitats and biomes based on abiotic factors, resource availability, and organismal traits.

SC.912.SL.2.1 Describe how Earth's habitats and biomes are characterized and used to organize patterns of organism distribution.

Benchmark Clarifications:

Clarification 1: Instruction includes defining habitats as the specific environments where organisms live.

Clarification 2: Instruction includes biomes as large-scale regions defined by climate, vegetation, and typical life forms.

Clarification 3: Instruction includes recognizing that similar biomes occur in different geographic locations.

Clarification 4: Instruction includes that organism distribution is not uniform across Planet Earth.

Clarification 5: Instruction includes marine habitat zones such as littoral, intertidal, subtidal, neritic, pelagic, benthic, and deep-ocean environments and the environmental gradients that distinguish them.

Clarification 6: Instruction includes comparing geographic distributions of habitats and biomes to identify large-scale patterns in organism distribution. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.SL.2.2 Analyze how abiotic factors influence the distribution of organisms within and across habitats and biomes.

Benchmark Clarifications:

Clarification 1: Instruction includes abiotic factors: temperature, water availability, light, soil composition, salinity, and climate patterns.

Clarification 2: Instruction includes analyzing tolerance ranges and limiting factors.

Clarification 3: Instruction includes that abiotic conditions vary spatially and temporally.

Clarification 4: Instruction includes using data or examples to connect abiotic conditions to organism presence or absence.

Clarification 5: Instruction includes substrate characteristics such as sand, mud, rock, shell, and coral and their influence on organism distribution and habitat use.

Clarification 6: Instruction includes salinity, dissolved oxygen, pH, temperature, and nutrient availability as abiotic factors influencing marine organism distribution.

Clarification 7: Instruction includes analyzing graphical, quantitative, and spatial data to examine relationships between abiotic factors and organism distribution. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 8: Instruction includes analyzing observations and evidence used to explain relationships between abiotic factors and organism distribution. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.2.3 Examine how the availability of resources influences organism distribution and abundance.

Benchmark Clarifications:

Clarification 1: Instruction includes resources: food, water, nutrients, shelter, and space.

Clarification 2: Instruction includes recognizing that resource availability can vary seasonally and regionally.

Clarification 3: Instruction includes distinguishing between resource-rich and resource-limited environments.

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Clarification 4: Instruction includes that resource availability affects population size and distribution.

Clarification 5: Instruction includes analyzing relationships among resource availability, population size, and organism distribution using quantitative and graphical data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain how changes in resource availability influence organism distribution and abundance. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.2.4 Analyze how structural, functional, and behavioral traits influence where organisms can survive and reproduce.

Benchmark Clarifications:

Clarification 1: Instruction includes traits: body structure, metabolism, water retention, and temperature regulation.

Clarification 2: Instruction includes behavioral traits: migration, dormancy, and habitat selection.

Clarification 3: Instruction includes that organisms exhibit different levels of tolerance to environmental conditions.

Clarification 4: Instruction includes using examples to connect traits to environmental conditions.

Clarification 5: Instruction includes using models to predict how changes in environmental conditions may influence organism survival and reproduction. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using evidence from organism traits and environmental conditions to explain patterns of survival and reproduction. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.2.5 Compare patterns of organism distribution across different terrestrial and aquatic biomes.

Benchmark Clarifications:

Clarification 1: Instruction includes comparing deserts, grasslands, forests, tundra, freshwater, and marine environments.

Clarification 2: Instruction includes similarities and differences in organism diversity across biomes.

Clarification 3: Instruction includes that biome-level patterns reflect underlying abiotic and resource conditions.

Clarification 4: Instruction includes freshwater marshes, swamps, floodplain wetlands, and spring-fed systems.

Clarification 5: Instruction includes comparing biodiversity, productivity, and organism distributions among estuarine, coral reef, mangrove, seagrass, nearshore, pelagic, and deep-ocean ecosystems.

Clarification 6: Instruction includes comparing biodiversity, productivity, and organism distributions among rivers, streams, lakes, ponds, wetlands, estuaries, and marine ecosystems.

Clarification 7: Instruction includes analyzing maps, graphical representations, and datasets to compare patterns of biodiversity and organism distribution among biomes. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 8: Instruction includes using spatial evidence to compare distributions of organisms across terrestrial and aquatic environments. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.2.6 Evaluate explanations for observed patterns in organism distribution.

Example: Analyze how larval dispersal, migration pathways, habitat fragmentation, and ocean-current transport influence the distribution and genetic diversity of Florida marine populations, such as sea turtles, reef fishes, corals, and estuarine organisms. Use examples from the Gulf Stream, Florida Keys coral reefs, seagrass communities, mangrove ecosystems, and estuarine habitats to explain how environmental conditions and movement among populations can affect allele frequencies and population connectivity.

Benchmark Clarifications:

Clarification 1: Instruction includes synthesizing abiotic factors, resource availability, and organismal traits.

Clarification 2: Instruction includes evaluating multiple factors rather than single-cause explanations.

Clarification 3: Instruction includes recognizing that distribution patterns can change over time.

Clarification 4: Instruction includes using evidence and data to support explanations and distribution.

Clarification 5: Instruction includes evaluating how ocean circulation, substrate type, salinity gradients, and habitat structure influence marine organism distributions.

Clarification 6: Instruction includes the use of biological indicators such as macroinvertebrates, algae, aquatic plants, amphibians, and fish to assess freshwater ecosystem health.

Clarification 7: Instruction includes constructing and evaluating evidence-based explanations using biological and environmental datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.3 Analyze how living organisms fulfill different ecological roles as producers, consumers, and decomposers and how these roles organize ecosystems and support life.

SC.912.SL.3.1 Explain ecological roles and how organisms are grouped based on how they obtain energy and matter.

Benchmark Clarifications:

Clarification 1: Instruction includes defining ecological roles as the functions organisms serve within ecosystems.

Clarification 2: Instruction includes ecological roles: producers, consumers, and decomposers.

Clarification 3: Instruction includes that living organisms with different species identities may serve similar ecological roles.

Clarification 4: Instruction includes distinguishing ecological roles from habitat or physical characteristics.

Clarification 5: Instruction includes comparing organisms that serve similar ecological roles in different ecosystems using evidence from organism characteristics and resource use. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.3.2 Explain how producers capture energy and support life within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes producers as living organisms that convert external energy into chemical energy.

Clarification 2: Instruction includes photosynthesis and chemosynthesis as mechanisms for energy capture.

Clarification 3: Instruction includes that producers form the base of most food webs.

Clarification 4: Instruction includes that the distribution of producers influences ecosystem structure.

Clarification 5: Instruction includes phytoplankton and macroalgae as primary producers, prey resources, oxygen producers, nutrient cyclers, habitat-forming organisms, and symbiotic partners within ecosystems.

Clarification 6: Instruction includes analyzing quantitative and graphical data related to producer productivity and energy availability within ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes analyzing representations and models of energy capture and transfer by producers within ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.3.3 Analyze how consumers obtain energy and transfer matter and energy through ecosystems.

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Benchmark Clarifications:

Clarification 1: Instruction includes consumers as living organisms that acquire energy by feeding on other living organisms.

Clarification 2: Instruction includes primary, secondary, and higher-level consumers.

Clarification 3: Instruction includes that food chains and food webs are representations of consumer interactions.

Clarification 4: Instruction includes that energy transfer between trophic levels is inefficient.

Clarification 5: Instruction includes analyzing relationships among trophic levels, energy transfer efficiency, and organism abundance using quantitative and graphical data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing models of food chains, food webs, and trophic interactions to explain energy transfer through ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.3.4 Analyze how decomposers recycle matter and contribute to ecosystem function.

Benchmark Clarifications:

Clarification 1: Instruction includes decomposers: bacteria and fungi.

Clarification 2: Instruction includes decomposition as the breakdown of organic material into simpler substances.

Clarification 3: Instruction includes that decomposers return nutrients to the environment.

Clarification 4: Instruction includes the connection between decomposition and nutrient cycling.

Clarification 5: Instruction includes using models to explain decomposition processes and nutrient recycling within ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes analyzing evidence of decomposition and nutrient recycling within ecosystems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.3.5 Examine how interactions among producers, consumers, and decomposers organize ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes trophic levels and their organization within ecosystems.

Clarification 2: Instruction includes that changes to one ecological role can affect other ecological roles within ecosystems.

Clarification 3: Instruction includes ecosystems as networks of interacting organisms and processes.

Clarification 4: Instruction includes that ecosystem organization reflects energy flow and matter cycling.

Clarification 5: Instruction includes relationships among algae, consumers, decomposers, and ecosystem productivity.

Clarification 6: Instruction includes analyzing quantitative and graphical evidence used to explain interactions among ecological roles within ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using ecosystem models to examine interactions among producers, consumers, decomposers, energy flow, and matter cycling. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.3.6 Evaluate how ecological roles collectively support ecosystem persistence and life.

Example: Analyze Florida ecosystems such as mangrove forests, seagrass beds, or freshwater wetlands to explain how producers, consumers, and decomposers collectively support ecosystem persistence through continuous energy input and nutrient cycling.

Using evidence from real-world Florida examples, explain how disruptions to any ecological role affect ecosystem function and the organisms that depend on it.

Benchmark Clarifications:

Clarification 1: Instruction includes that ecosystems need continuous energy input and nutrient recycling.

Clarification 2: Instruction includes that ecosystems depend on the functioning of all ecological roles.

Clarification 3: Instruction includes estuaries as highly productive transition zones that support biodiversity, nutrient cycling, nursery habitats, and ecological connectivity.

Clarification 4: Instruction includes analyzing quantitative and graphical data related to energy flow, nutrient cycling, and ecosystem stability. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating ecosystem models and ecological evidence to explain how ecological roles support ecosystem persistence. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and evaluating evidence-based explanations using ecological observations, datasets, and investigations to explain ecosystem persistence. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to ecosystem ecology, energy flow, and nutrient cycling and how scientific understanding of ecosystem function has changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.4 Analyze how living organisms interact within ecosystems through competition, predation, symbiosis, cooperation, and resource use to shape community structure and biodiversity.

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SC.912.SL.4.1 Describe the types of interactions among organisms within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes interaction types: competition, predation, symbiosis, cooperation, and resource use.

Clarification 2: Instruction includes that interactions occur within and among populations, including intraspecific and interspecific competition.

Clarification 3: Instruction includes that multiple interaction types may occur simultaneously.

Clarification 4: Instruction includes that interactions influence how organisms live and use their environment.

Clarification 5: Instruction includes using observations, ecological evidence, and examples to identify and compare different interaction types among organisms. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.4.2 Analyze how competition for limited resources influences living organism abundance and distribution.

Example: Analyze a Florida seagrass meadow ecosystem to investigate how living organisms compete for limited resources. Using species data, diagrams, or case studies, explain how competition for light, space, nutrients, and food affects population patterns within the ecosystem.

Benchmark Clarifications:

Clarification 1: Instruction includes competition for food, space, water, light, and nutrients.

Clarification 2: Instruction includes that competition occurs within species and between species.

Clarification 3: Instruction includes that resource availability can change over time.

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Clarification 4: Instruction includes analyzing quantitative, graphical, and spatial data to evaluate relationships among resource availability, organism abundance, and distribution. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using evidence from ecological observations, investigations, and datasets to explain the effects of competition on living organism abundance and distribution. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.4.3 Analyze how predation influences population sizes, behaviors, and community structure.

Benchmark Clarifications:

Clarification 1: Instruction includes predator-prey relationships within food webs.

Clarification 2: Instruction includes that predation can affect survival, reproduction, and behavior.

Clarification 3: Instruction includes that changes in predator or prey populations affect other living organisms.

Clarification 4: Instruction includes recognizing predation as an interaction that transfers energy through ecosystems.

Clarification 5: Instruction includes analyzing quantitative and graphical data to identify patterns in predator-prey relationships and population change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing predator-prey models, food webs, and interaction networks to explain how predation influences populations and communities. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.4.4 Examine how symbiotic and cooperative interactions affect organisms and communities.

Example: Examine parasitic organisms in the coral reef communities of the Florida Keys to analyze how parasitic relationships affect the survival and reproductive success of host

organisms. Using specific reef examples, explain how parasites influence the health of living organisms and shape community structure within the reef ecosystem.

Benchmark Clarifications:

Clarification 1: Instruction includes mutualism, commensalism, and parasitism.

Clarification 2: Instruction includes cooperative behaviors within and among species.

Clarification 3: Instruction includes that interactions may benefit one, both, or neither living organism.

Clarification 4: Instruction includes coral-zooxanthellae symbiosis, cleaning symbioses, and microbial symbioses within marine ecosystems.

Clarification 5: Instruction includes using ecological models and interaction diagrams to examine symbiotic and cooperative relationships among organisms. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using evidence and examples to explain how symbiotic and cooperative interactions influence organism survival, reproduction, and community structure. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.4.5 Analyze how interactions among living organisms shape community structure.

Benchmark Clarifications:

Clarification 1: Instruction includes community composition, species abundance, and biodiversity.

Clarification 2: Instruction includes that interactions influence which living organisms can coexist.

Clarification 3: Instruction includes that changes in interactions can alter community composition.

Clarification 4: Instruction includes using interaction networks or food webs to illustrate community structure.

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Clarification 5: Instruction includes relationships among substrate type, species abundance, biodiversity, habitat availability, and community structure.

Clarification 6: Instruction includes analyzing quantitative, graphical, and ecological data used to describe community composition, species abundance, and biodiversity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using food webs, interaction networks, and ecosystem models to explain how interactions influence community organization and biodiversity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.4.6 Evaluate how living organism interactions contribute to patterns of biodiversity within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes biodiversity as the variety of life within a community.

Clarification 2: Instruction includes evaluating how interactions can increase or decrease biodiversity.

Clarification 3: Instruction includes that biodiversity varies across ecosystems and environments.

Clarification 4: Instruction includes barrier islands as ecological systems that support biodiversity, influence estuarine conditions, provide habitat, and contribute to ecosystem resilience.

Clarification 5: Instruction includes analyzing quantitative, graphical, and spatial data to evaluate how organism interactions influence biodiversity patterns within ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using community and ecosystem models to evaluate how interactions among organisms influence biodiversity and ecosystem stability. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes constructing and evaluating evidence-based explanations using ecological observations, investigations, and biodiversity data to support conclusions about biodiversity patterns. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.SL.5 Analyze how populations and communities grow, stabilize, or change over time as a result of reproduction, survival, migration, limiting factors, and species interactions.

SC.912.SL.5.1 Describe how reproduction contributes to population growth over time.

Benchmark Clarifications:

Clarification 1: Instruction includes reproduction rates influence population size.

Clarification 2: Instruction includes that populations may grow exponentially under ideal conditions.

Clarification 3: Instruction includes that population growth varies among species.

Clarification 4: Instruction includes interpreting population-growth graphs and mathematical population models. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using population-growth models to examine how reproduction influences population size over time. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.5.2 Analyze how survival and mortality affect population size and structure.

Benchmark Clarifications:

Clarification 1: Instruction includes that survival is the ability of individuals to live long enough to reproduce.

Clarification 2: Instruction includes that mortality is the loss of individuals from a population.

Clarification 3: Instruction includes that survival rates vary across life stages.

Clarification 4: Instruction includes that survival and mortality influence population stability.

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Clarification 5: Instruction includes analyzing survivorship, mortality, and population structure data to identify patterns in population change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain relationships among survival, mortality, and population stability. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.5.3 Examine how migration influences population size and distribution.

Benchmark Clarifications:

Clarification 1: Instruction includes immigration and emigration.

Clarification 2: Instruction includes that migration can increase or decrease population size.

Clarification 3: Instruction includes that migration alters population distribution and density.

Clarification 4: Instruction includes that migration patterns may change over time.

Clarification 5: Instruction includes larval dispersal, migration pathways, and ocean-current transport as factors influencing population size, distribution, gene flow, and connectivity among marine populations.

Clarification 6: Instruction includes analyzing maps, migration data, and population-distribution patterns to explain how migration influences population size and distribution. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using observations and evidence to explain how migration affects population dynamics across locations and over time. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.5.4 Analyze how limiting factors regulate population growth and contribute to population stability.

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Example: Analyze information on invasive lionfish populations in Florida reef ecosystems to identify limiting factors such as food availability, space, predation, and human removal. Distinguish density-dependent and density-independent factors and explain how these factors determine carrying capacity and prevent indefinite population growth.

Benchmark Clarifications:

Clarification 1: Instruction includes limiting factors: food, water, space, disease, and predation.

Clarification 2: Instruction includes density-dependent and density-independent limiting factors.

Clarification 3: Instruction includes carrying capacity as the maximum population size an environment can support under existing resource availability and environmental conditions.

Clarification 4: Instruction includes that limiting factors prevent indefinite population growth.

Clarification 5: Instruction includes analyzing quantitative and graphical data to evaluate relationships among limiting factors, carrying capacity, and population growth. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using population models to predict responses to limiting factors and carrying capacity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using observations and evidence to explain how limiting factors influence population stability and change. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.5.5 Analyze how interactions among species influence population and community dynamics.

Benchmark Clarifications:

Clarification 1: Instruction includes competition, predation, and symbiotic relationships.

Clarification 2: Instruction includes that interactions can increase, decrease, or stabilize populations.

Clarification 3: Instruction includes recognizing indirect effects on other species.

Clarification 4: Instruction includes that community level changes result from interacting populations.

Clarification 5: Instruction includes the role of ocean currents in transporting organisms, nutrients, larvae, and propagules among marine communities.

Clarification 6: Instruction includes Hardy-Weinberg equilibrium as a mathematical model used to predict expected allele and genotype frequencies and evaluate whether evolutionary mechanisms are influencing a population.

Clarification 7: Instruction includes analyzing allele and genotype frequencies using Hardy-Weinberg models and compare observed and expected population data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 8: Instruction includes using food webs, interaction networks, and Hardy-Weinberg models to predict genotype frequencies and evaluate evolutionary change within populations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.5.6 Evaluate explanations for changes in populations and communities over time.

Example: Analyze long-term data on Eastern oyster (Crassostrea virginica) populations in Apalachicola Bay to evaluate explanations in population abundance over time. Using the data, determine how reproduction, survival, migration, limiting factors, and species interactions contribute to observed patterns of growth, fluctuation, or decline in the oyster population and the broader estuarine community.

Benchmark Clarifications:

Clarification 1: Instruction includes synthesizing reproduction, survival, migration, limiting factors, and interactions.

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Clarification 2: Instruction includes that populations and communities may grow, stabilize, fluctuate, or decline.

Clarification 3: Instruction includes recognizing patterns across different ecosystems.

Clarification 4: Instruction includes using data or evidence to support explanations of change.

Clarification 5: Instruction includes evaluating deviations from Hardy-Weinberg equilibrium caused by mutation, migration, genetic drift, nonrandom mating, and natural selection.

Clarification 6: Instruction includes analyzing quantitative, graphical, and spatial data to evaluate explanations for population and community change over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes evaluating strengths and limitations of population models and evidence-based explanations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 8: Instruction includes constructing and evaluating evidence-based explanations using biological observations, investigations, and population datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.6 Analyze and interpret evidence to explain how variation within populations influences survival, reproduction, and responses to environmental conditions; and how differences in survival and reproductive success can change population characteristics over time.

SC.912.SL.6.1 Describe sources of variations within a population.

Example: Examine photographs, videos, and data on Florida manatees (Trichechus manatus latirostris) to identify variations in traits such as body size, skin coloration, scarring patterns, behavior, and life-history characteristics. Using specific examples, describe how individual manatees differ from one another and explain how these differences demonstrate that variation is a measurable characteristic of the manatee population.

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Benchmark Clarifications:

Clarification 1: Instruction includes variations in traits: size, coloration, behavior, physiology, or life-history characteristics (age or reproductive status).

Clarification 2: Instruction includes variation as a measurable characteristic of populations.

Clarification 3: Instruction includes analyzing variation using quantitative, graphical, or population data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing observable and measurable variation among individuals within a population using scientific observations, images, and datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.6.2 Analyze how variation influences individual survival under different environmental conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes that environmental conditions can favor some traits over others.

Clarification 2: Instruction includes abiotic and biotic factors as influences on survival.

Clarification 3: Instruction includes that not all individuals are equally likely to survive.

Clarification 4: Instruction includes connecting trait differences to survival outcomes using evidence.

Clarification 5: Instruction includes analyzing quantitative and graphical data to identify relationships among variation, environmental conditions, and survival outcomes. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using evidence from observations, investigations, and datasets to explain how variation influences survival under different environmental conditions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.SL.6.3 Analyze how variation affects reproductive success within populations.

Benchmark Clarifications:

Clarification 1: Instruction includes that individuals differ in reproductive output and reproductive success rates.

Clarification 2: Instruction includes traits that influence mating success, fertility, or offspring survival.

Clarification 3: Instruction includes that reproduction contributes to which traits are more common in a population.

Clarification 4: Instruction includes analyzing quantitative and graphical data to evaluate how differences in reproductive success influence population characteristics over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence used to explain relationships among variation, reproductive success, and population change. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.6.4 Examine how populations respond to changes in environmental conditions based on existing variation.

Example: Analyze telemetry maps, road crossing data, or population monitoring data sets for the Florida panther (Puma concolor coryi) to examine responses to habitat fragmentation caused by road development and land use change. Using the data, analyze how variation in movement behavior and habitat use leads to short-term shifts in distribution and long-term changes in population structure and abundance.

Benchmark Clarifications:

Clarification 1: Instruction includes changes in temperature, resource availability, predation pressure, and habitat conditions.

Clarification 2: Instruction includes that populations may respond differently depending on trait variation.

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Clarification 3: Instruction includes responses: shifts in abundance, distribution, or population structure.

Clarification 4: Instruction includes analyzing quantitative, graphical, and spatial data to identify population responses to environmental change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using models to predict population responses to environmental change based on existing variation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain how populations respond to environmental change based on existing variation. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.6.5 Analyze how differences in survival and reproductive success influence population characteristics over time.

Example: Analyze multiyear data from the Florida Fish and Wildlife Commission (FWC) Florida Black Bear population monitoring reports, including bear abundance estimates, female reproductive success, and cub survival rates, to track changes in population characters of the Florida black bear (Ursus americanus floridus). Identify patterns of change across generations and explain how differences in survival and reproduction influence overall population traits.

Benchmark Clarifications:

Clarification 1: Instruction includes changes in trait distributions within populations.

Clarification 2: Instruction includes that population characteristics can shift across multiple generations.

Clarification 3: Instruction includes recognizing patterns of increase or decrease in specific traits.

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Clarification 4: Instruction includes analyzing population data collected across multiple generations to identify changes in population characteristics over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using models to examine how differences in survival and reproductive success influence population characteristics across generations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using evidence from observations, investigations, and long-term datasets to explain patterns of population change. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to population change, adaptation, and natural selection and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.6.6 Evaluate explanations for observed changes in population characteristics using evidence.

Benchmark Clarifications:

Clarification 1: Instruction includes synthesizing variation, survival, reproduction, and environmental conditions.

Clarification 2: Instruction includes evaluating multiple explanations rather than single factor causes.

Clarification 3: Instruction includes recognizing that population change is gradual and iterative.

Clarification 4: Instruction includes analyzing quantitative and graphical data to evaluate explanations for changes in population characteristics. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating strengths and limitations of models used to explain changes in population characteristics over time. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes constructing and evaluating evidence-based explanations using biological observations, investigations, and population datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.7 Analyze how ecosystems develop, respond to disturbance, and recover over time through ecological succession, resilience, and species contributions.

SC.912.SL.7.1 Describe how ecosystems develop over time through interactions among living organisms and their environment.

Example: Examine a developing ecosystem, such as newly formed sand dunes along the Florida Panhandle coast after a hurricane or a recovering longleaf pine forest following a fire, to describe how ecosystems change over time. Using observations, images, or data, describe changes in species composition and structure to explain how interactions between organisms and environmental conditions drive ecosystem development across different timescales.

Benchmark Clarifications:

Clarification 1: Instruction includes ecosystems as dynamic systems that change over time.

Clarification 2: Instruction includes that ecosystem development involves changes in species composition and structure.

Clarification 3: Instruction includes recognizing that development occurs over varying timescales.

Clarification 4: Instruction includes barrier-island succession, dune development, and coastal ecosystem establishment following a disturbance.

Clarification 5: Instruction includes analyzing patterns of ecosystem development using graphical, quantitative, and spatial data collected across different timescales. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes analyzing observations, images, and ecological data to identify changes in species composition and ecosystem structure over time. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.7.2 Analyze the process of ecological succession and how it contributes to ecosystem development.

Benchmark Clarifications:

Clarification 1: Instruction includes primary and secondary succession.

Clarification 2: Instruction includes changes in species composition over successional stages.

Clarification 3: Instruction includes that succession is influenced by environmental conditions and species interactions.

Clarification 4: Instruction includes analyzing ecological data to identify changes in species composition and ecosystem structure across successional stages. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes diagrams, models, or examples to illustrate succession patterns and succession models to predict ecosystem development under changing environmental conditions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain patterns of ecological succession and ecosystem development. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.7.3 Examine how ecosystems respond to disturbances.

Benchmark Clarifications:

Clarification 1: Instruction includes disturbances: fire, storms, flooding, disease, and human activity.

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Clarification 2: Instruction includes that disturbances vary in intensity, frequency, and scale.

Clarification 3: Instruction includes can alter species composition, ecosystem structure, and resource availability.

Clarification 4: Instruction includes recognizing that not all disturbances have the same effects.

Clarification 5: Instruction includes analyzing quantitative, graphical, and spatial data to compare ecosystem responses to disturbances of different intensities, frequencies, and scales. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing observations, investigations, and ecological evidence to explain ecosystem responses to disturbances. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.7.4 Analyze how resilience influences ecosystem recovery after disturbance.

Benchmark Clarifications:

Clarification 1: Instruction includes resilience as the ability of an ecosystem to recover or reorganize following disturbance.

Clarification 2: Instruction includes that recovery rates vary among ecosystems.

Clarification 3: Instruction includes that resilience is influenced by species diversity and ecosystem structure.

Clarification 4: Instruction includes short-term and long-term recovery processes.

Clarification 5: Instruction includes analyzing quantitative and graphical data to compare recovery rates and resilience among ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating ecosystem recovery models using observational and quantitative evidence. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 7: Instruction includes using observations and evidence to explain how ecosystem structure, diversity, and environmental conditions influence resilience and recovery. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.7.5 Analyze how different species contribute to ecosystem recovery and long-term stability.

Example: Analyze water-level records and species abundance data from a Central Florida freshwater marsh along the St. Johns River to explain how changes in key species contribute to ecosystem recovery and long-term stability following environmental disturbance.

Benchmark Clarifications:

Clarification 1: Instruction includes pioneer species and other organisms that modify environmental conditions.

Clarification 2: Instruction includes that species roles influence nutrient cycling, energy flow, and habitat structure.

Clarification 3: Instruction includes that the presence or absence of certain species can affect recovery pathways.

Clarification 4: Instruction includes analyzing ecological datasets to identify relationships among species abundance, ecosystem recovery, and stability. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using ecosystem models to explain how species contributions influence recovery pathways and long-term ecosystem stability. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain how specific species contribute to ecosystem recovery and long-term stability. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.SL.7.6 Evaluate explanations for patterns of ecosystem development, disturbance response, and recovery over time.

Benchmark Clarifications:

Clarification 1: Instruction includes synthesizing succession, disturbance, resilience, and species roles.

Clarification 2: Instruction includes recognizing that ecosystems can follow multiple recovery pathways.

Clarification 3: Instruction includes comparing patterns across different ecosystems.

Clarification 4: Instruction includes analyzing quantitative, graphical, and spatial data to evaluate explanations for ecosystem development, disturbance response, resilience, and recovery. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using data, models, and evidence to construct and evaluate explanations of ecosystem development, disturbance response, and recovery. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and evaluating evidence-based explanations using ecological observations, investigations, and long-term datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to ecological succession, ecosystem dynamics, and disturbance ecology and how scientific explanations can change as new evidence becomes available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.8 Analyze how energy flows and matter cycles through living systems across ecosystems, linking organisms, populations, and environments.

SC.912.SL.8.1 Describe how energy enters living systems and is transferred among living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes energy entering ecosystems primarily through producers.

Clarification 2: Instruction includes that energy flows through organisms in one direction.

Clarification 3: Instruction includes recognizing energy transfer across trophic levels.

Clarification 4: Instruction includes that energy is transformed and eventually dissipated as heat.

Clarification 5: Instruction includes analyzing quantitative and graphical data to identify patterns of energy transfer among trophic levels. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using energy-flow diagrams, food webs, and quantitative representations to explain how energy enters ecosystems and is transferred among organisms. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.8.2 Analyze how energy is transferred among producers, consumers and decomposers.

Example: Analyze a food web from the Florida Everglades (sawgrass → apple snails → wading birds → alligators) and construct an energy pyramid to calculate the approximate energy available at each trophic level using a 10% energy transfer efficiency. Use these calculations and organism abundance data from the Everglades to explain why producers are most abundant and why populations decrease at higher trophic levels as available energy declines.

Benchmark Clarifications:

Clarification 1: Instruction includes food chains and food webs as representations of energy transfers.

Clarification 2: Instruction includes that energy transfer between trophic levels is inefficient.

Clarification 3: Instruction includes recognizing that less energy is available at higher trophic levels.

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Clarification 4: Instruction includes phytoplankton and macroalgae as foundational sources of energy supporting marine food webs and ecosystem productivity.

Clarification 5: Instruction includes constructing and interpreting energy pyramids and quantitative representations of trophic-level energy transfer. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and using food webs, food chains, and energy pyramids to model trophic-level energy transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using evidence and ecological observations to explain patterns of energy transfer among producers, consumers, and decomposers. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.8.3 Describe how matter cycles through living systems within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes matter cycling through producers, consumers, and decomposers.

Clarification 2: Instruction includes that matter is conserved as it changes form and location.

Clarification 3: Instruction includes nutrient incorporation into living tissues.

Clarification 4: Instruction includes the release of matter back into the environment through biological processes.

Clarification 5: Instruction includes analyzing graphical and quantitative representations of matter cycling in ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using diagrams and systems models to represent the movement of matter through producers, consumers, decomposers, and the environment. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 7: Instruction includes analyzing observations and evidence used to explain matter cycling within ecosystems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.8.4 Analyze how biological processes connect ecosystems to biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes carbon, nitrogen, phosphorus, and hydrologic cycles.

Clarification 2: Instruction includes the roles of living organisms in moving and transforming elements.

Clarification 3: Instruction includes that biological activity links the biosphere with other Earth systems.

Clarification 4: Instruction includes the differences in cycling rates among elements.

Clarification 5: Instruction includes marine nutrient cycling involving phytoplankton, macroalgae, consumers, decomposers, microorganisms, and marine sediments.

Clarification 6: Instruction includes analyzing data related to carbon, nitrogen, phosphorus, and hydrologic cycles to identify patterns and rates of matter movement. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using systems models to represent movement of matter among living organisms and Earth systems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 8: Instruction includes using observations and evidence to explain how biological processes influence biogeochemical cycles. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 9: Instruction includes examining historical developments related to nutrient cycling, ecosystem ecology, and biogeochemical cycles and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.SL.8.5 Examine how energy flow and matter cycling connect organisms, populations, and their environments.

Example: Examine the role of the American alligator (Alligator mississippiensis) in the Florida Everglades to explain how energy flow and matter cycling connect organisms, populations, and environmental conditions within an integrated system. Consider alligator feeding, nutrient redistribution, and habitat modification to describe how changes to one species influences energy pathways and matter movement across the entire Everglades system.

Benchmark Clarifications:

Clarification 1: Instruction includes population size and structure influencing energy and matter use.

Clarification 2: Instruction includes environmental conditions affecting productivity and cycling rates.

Clarification 3: Instruction includes interactions among populations influencing energy pathways.

Clarification 4: Instruction includes estuarine systems as examples of interactions among populations, energy flow, matter cycling, and environmental conditions.

Clarification 5: Instruction includes analyzing quantitative and graphical data to identify relationships among population characteristics, productivity, and matter cycling. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using systems models to explain relationships among organisms, populations, energy flow, matter cycling, and environmental conditions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using ecological observations and evidence to explain connections among organisms, populations, and environmental conditions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.SL.8.6 Evaluate how changes in energy flow and matter cycling affect ecosystem structure and function.

Example: Examine how changes in energy flow and nutrient cycling associated with sawgrass (Cladium jamaicense) in the Florida Everglades affect ecosystem structure and function by using productivity data, nutrient concentration measurements, or energy pyramid calculations to analyze feedbacks among plant abundance, consumer populations, and wetland conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes the effects of altered energy input and nutrient availability.

Clarification 2: Instruction includes evaluating the consequences for organism abundance and distribution.

Clarification 3: Instruction includes recognizing feedbacks between biological and environmental processes.

Clarification 4: Instruction includes analyzing quantitative, graphical, and spatial data to evaluate effects of changes in energy flow and matter cycling on ecosystem structure and function. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating ecological models and quantitative evidence to determine effects of altered energy flow and matter cycling. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and evaluating evidence-based explanations using ecological observations, investigations, and ecosystem datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to ecosystem ecology, energy flow, and nutrient cycling and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.SL.9 Evaluate how anthropogenic activities affect living systems by altering habitats, species interactions, and ecosystem processes; and the strategies used to conserve biodiversity and sustain ecological function.

SC.912.SL.9.1 Describe anthropogenic activities that interact with living systems.

Example: Identify how seagrass restoration in St. Andrew's Bay, Bay County, Florida, represents a human activity that interacts with living systems by altering physical conditions such as sediment stability and water clarity and how plant and animal communities respond differently to short-term restoration actions and long-term habitat improvement.

Benchmark Clarifications:

Clarification 1: Instruction includes human activities: land use change, conservation, agriculture, urban development, habitat restoration, resource extraction, and infrastructure construction.

Clarification 2: Instruction includes distinguishing between natural and human-induced ecosystem processes.

Clarification 3: Instruction includes analyzing spatial and environmental data to examine relationships between anthropogenic activities and living systems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using observations, maps, case studies, and ecological evidence to identify human activities that influence living systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.9.2 Analyze how habitat alteration influences living organism distribution and population dynamics.

Benchmark Clarifications:

Clarification 1: Instruction includes habitat loss, fragmentation, and modification.

Clarification 2: Instruction includes that altered habitats can change resource availability and suitability.

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Clarification 3: Instruction includes that species respond differently to habitat change.

Clarification 4: Instruction includes using examples or data to connect habitat alteration to population patterns.

Clarification 5: Instruction includes analyzing maps, spatial data, and population datasets to evaluate relationships between habitat alteration, organism distribution, and population dynamics. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using models to predict population responses to habitat loss, habitat fragmentation, and habitat modification. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using observations and evidence to explain how habitat alteration influences organism distribution and population dynamics. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.9.3 Analyze how anthropogenic activities alter interactions among species.

Example: Examine sea turtle nesting success rates near the Archie Carr National Wildlife Refuge in Brevard County, Florida, and consider the impact of artificial beachfront lighting on predator-prey and other species interactions that affect sea turtle nesting success.

Benchmark Clarifications:

Clarification 1: Instruction includes changes to competition, predation, mutualism, and parasitic relationships.

Clarification 2: Instruction includes that altered interactions can affect population balance and community structures.

Clarification 3: Instruction includes recognizing direct and indirect effects on other species.

Clarification 4: Instruction includes analyzing quantitative and graphical data to identify patterns associated with altered species interactions. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes using ecological models and interaction networks to examine how anthropogenic activities influence species interactions and community structure. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing ecological observations and evidence to explain how anthropogenic activities alter interactions among species. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.9.4 Analyze how anthropogenic activities influence ecosystem processes.

Benchmark Clarifications:

Clarification 1: Instruction includes ecosystem processes: energy flow, nutrient cycling, primary productivity, and decomposition.

Clarification 2: Instruction includes recognizing that ecosystem processes operate at multiple scales.

Clarification 3: Instruction includes that changes in ecosystem processes can affect ecosystem structure and function.

Clarification 4: Instruction includes analyzing quantitative and graphical data to evaluate changes in energy flow, nutrient cycling, primary productivity, and decomposition. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using data and models to examine changes in ecosystem processes associated with anthropogenic activities. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain how anthropogenic activities influence ecosystem processes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.9.5 Analyze patterns of biodiversity change associated with anthropogenic activities.

Example: Analyze and evaluate long-term lionfish monitoring data sets from the Florida Keys such as reef fish surveys or removal records. Use the data to determine how this

human introduced species has altered patterns of biodiversity by identifying increases, decreases, or shifts in native species abundance; composition; and community structure over time.

Benchmark Clarifications:

Clarification 1: Instruction includes biodiversity at genetic, species, and ecosystem levels.

Clarification 2: Instruction includes evaluating data showing increases, decreases, or shifts in biodiversity.

Clarification 3: Instruction includes interpreting biodiversity datasets, indices, and graphical representations to evaluate patterns of biodiversity change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using models to examine how anthropogenic activities influence biodiversity patterns across ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using observations, investigations, and ecological evidence to explain patterns of biodiversity change associated with anthropogenic activities. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.9.6 Evaluate strategies used to conserve biodiversity and sustain ecological function.

Benchmark Clarifications:

Clarification 1: Instruction includes strategies: protected areas, habitat restoration, species management, and resource regulation.

Clarification 2: Instruction includes that strategies have limitations, trade-offs, and varying effectiveness.

Clarification 3: Instruction includes recognizing uncertainty and variability in biological outcomes.

Clarification 4: Instruction includes evaluating strategies using scientific evidence and biological data.

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Clarification 5: Instruction includes analyzing scientific data used to evaluate the effectiveness of conservation and management strategies. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating strengths and limitations of conservation and management models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes constructing and evaluating evidence-based explanations using ecological observations, investigations, and conservation datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 8: Instruction includes examining historical developments related to conservation biology, ecosystem management, and biodiversity protection and how scientific explanations and management strategies have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.SL.9.7 Evaluate explanations for how anthropogenic activities and management strategies influence living systems over time.

Benchmark Clarifications:

Clarification 1: Instruction includes synthesizing habitat change, species interactions, and ecosystem processes.

Clarification 2: Instruction includes recognizing that outcomes may differ across locations and ecosystems.

Clarification 3: Instruction includes using multiple sources of evidence: population data, maps, and models.

Clarification 4: Instruction includes analyzing quantitative, graphical, and spatial data to evaluate the effects of anthropogenic activities and management strategies across locations and time periods. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes evaluating strengths and limitations of models used to explain the effects of anthropogenic activities and management strategies on living systems over time. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and evaluating evidence-based explanations using ecological observations, investigations, population datasets, maps, and models. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to conservation, ecosystem management, biodiversity protection, and environmental stewardship and how scientific explanations and management practices have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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The Science of Cell Biology

How cells are structured and regulated, how they communicate and manage energy, grow and divide, and pass on genetic information that drives development, function, and the continuity of life.

Grades 9-12

SC.912.CB.1 Explain that all living organisms are made of cells that arise from preexisting cells and perform essential life processes through their specialized structures, membranes, metabolic pathways, and communication systems, and analyze applications of cells and tissues in modern science and medicine.

SC.912.CB.1.1 Recall the principles of Cell Theory.

Benchmark Clarifications:

Clarification 1: Instruction includes the fundamental knowledge that all living things are made of cells, cells are the basic unit of life, and cells arise from pre-existing cells.

Clarification 2: Instruction includes that Matthias Schleiden and Theodor Schwann are credited with developing the first and second tenets of Cell Theory during 1838-1839.

Clarification 3: Instruction includes examining historical developments related to Cell Theory and how scientific explanations of cellular organization changed as new observations and evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.2 Recognize that all living things are made of cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that cells are the basic structural and functional units of life.

Clarification 2: Instruction includes that organisms can be unicellular (one cell) or multicellular (many cells).

Clarification 3: Instruction includes that the 17th century scientist Robert Hooke was the first to use the term “cell” in biology to describe the structures he observed in cork.

Clarification 4: Instruction includes examining historical developments related to the discovery of cells and how improvements in scientific tools and observations contributed to modern cell theory. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.3 Recognize that cells are the basic unit of life.

Benchmark Clarifications:

Clarification 1: Instruction includes that cells carry out all life processes: growth, reproduction, and metabolism.

Clarification 2: Instruction includes that all life processes occur within cells and depend on coordinated cellular structures and functions.

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Clarification 3: Instruction includes comparing cellular functions among unicellular and multicellular organisms using observations and evidence. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.4 Recognize that cells arise from pre-existing cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that new cells are formed through cell division: mitosis and meiosis.

Clarification 2: Instruction includes that this principle disproved the idea of spontaneous generation.

Clarification 3: Instruction includes using evidence from observations and investigations to explain that new cells arise from existing cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes examining historical developments related to spontaneous generation, biogenesis, and Cell Theory and how scientific explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.5 Identify how metabolism is the sum of all chemical reactions that occur within living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes that metabolism maintains life, provides energy for cell processes, and synthesizes new organic material.

Clarification 2: Instruction includes the two main types of metabolic processes: anabolism (requires energy) and catabolism (releases energy).

Clarification 3: Instruction includes examples of anabolism such as protein synthesis, glycogenesis, and photosynthesis in plants and examples of catabolism such as glycolysis, lipolysis, and breaking down proteins into amino acids (protein catabolism).

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Clarification 4: Instruction includes analyzing graphical and quantitative data related to rates of metabolic processes and energy use. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing representations of metabolic pathways to explain relationships among energy transfer, matter transformation, anabolism, and catabolism. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and evidence to explain how metabolic processes support cellular function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.6 Explain passive transport through a cell membrane until equilibrium is achieved.

Benchmark Clarifications:

Clarification 1: Instruction includes that the movement of particles from an area of high concentration to low concentration is called diffusion.

Clarification 2: Instruction includes that osmosis is a specific type of diffusion involving water molecules moving across a selectively permeable membrane.

Clarification 3: Instruction includes analyzing graphical and quantitative data related to diffusion, osmosis, and equilibrium. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing concentration gradients using diagrams, graphs, and models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using observations and investigations to explain passive transport across cell membranes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.7 Explain active transport through a cell membrane against a concentration gradient.

Benchmark Clarifications:

Clarification 1: Instruction includes that active transport requires energy (adenosine triphosphate – ATP) to move against a concentration gradient.

Clarification 2: Instruction includes that a cell membrane is selectively permeable.

Clarification 3: Instruction includes comparing passive and active transport using energy and concentration-gradient data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using models and representations to explain active transport across cell membranes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using observations and evidence to explain mechanisms of active transport. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.8 Describe the structure of a prokaryotic cell.

Benchmark Clarifications:

Clarification 1: Instruction includes the structure of a prokaryotic cell which includes ribosomes, cell membrane (plasma membrane), cytoplasm, nucleoid region, flagella, cell wall, and capsules.

Clarification 2: Instruction includes that prokaryotic cells lack membrane-bound organelles like a nucleus or mitochondria.

Clarification 3: Instruction includes that prokaryotic organisms are unicellular.

Clarification 4: Instruction includes using cell models and representations to identify and explain structures found in prokaryotic cells. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations and microscopic evidence used to identify prokaryotic cell structures. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.9 Describe the structure of a eukaryotic cell.

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Benchmark Clarifications:

Clarification 1: Instruction includes the structure of a eukaryotic cell which includes nucleus, vacuoles, lysosomes, cytoskeleton, ribosomes, endoplasmic reticulum, Golgi apparatus, chloroplasts, mitochondria, cell wall, and cell membrane.

Clarification 2: Instruction includes that eukaryotic organisms are unicellular or multicellular.

Clarification 3: Instruction includes using cell models and representations to identify and explain the functions of eukaryotic cell structures. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing observations and microscopic evidence used to identify eukaryotic cell structures. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.10 Explain the structure and function of a cell membrane.

Benchmark Clarifications:

Clarification 1: Instruction includes the phospholipid bilayer.

Clarification 2: Instruction includes the fluid mosaic model.

Clarification 3: Instruction includes that a selectively permeable membrane allows certain substances to pass through while prohibiting others.

Clarification 4: Instruction includes analyzing quantitative and graphical data related to membrane transport and permeability. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating membrane models using evidence about phospholipids, proteins, and membrane function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and investigations to explain relationships between membrane structure and membrane function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.1.11 Recognize that animals, plants, fungi, and protists are made of eukaryotic cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the similarities and differences amongst animals, plants, fungi and protists.

Clarification 2: Instruction includes comparing structural similarities and differences among eukaryotic cells using observations, images, models, and evidence. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.12 Recognize that the communication in eukaryotic cells happens in coordinated ways for cells to function correctly.

Benchmark Clarifications:

Clarification 1: Instruction includes that cells must receive and process signals coming from their neighbors, integrate the information they receive, and transmit signals to target cells and cellular structures to coordinate appropriate responses.

Clarification 2: Instruction includes the possibility for eukaryotic cells to signal through direct contact.

Clarification 3: Instruction includes using models and representations to explain how cells communicate, process information, and coordinate responses. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence from observations and investigations used to explain cellular communication and coordination. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.1.13 Analyze the use of cell and tissue cultures in scientific research, medicine, agriculture, and biotechnology.

Example: Investigate factors that influence cell growth in culture.

Example: Evaluate the use of stem cells in regenerative medicine.

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Example: Analyze biomanufacturing processes used to produce vaccines or therapeutic proteins.

Benchmark Clarifications:

Clarification 1: Instruction includes cell culture, tissue culture, and sterile laboratory techniques.

Clarification 2: Instruction includes stem cells and their applications in research, medicine, and biotechnology.

Clarification 3: Instruction includes the use of cultured cells and tissues in vaccine development, drug testing, regenerative medicine, and biological research.

Clarification 4: Instruction includes biomanufacturing processes that use living cells to produce biological products.

Clarification 5: Instruction includes analyzing data used to evaluate growth, viability, and productivity of cultured cells and tissues. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2 Explain how photosynthesis and chemosynthesis convert energy into usable organic molecules through distinct biochemical pathways; and evaluate the environmental factors and ecological roles that influence and support life on Earth.

SC.912.CB.2.1 Describe the process of photosynthesis.

Benchmark Clarifications:

Clarification 1: Instruction includes the chemical reaction where water, carbon dioxide, chlorophyll, and energy are used as raw materials to produce glucose, oxygen, and water.

Clarification 2: Instruction includes the role of chlorophyll and chloroplasts in photosynthesis.

Clarification 3: Instruction includes the use of the chemical formula for photosynthesis to demonstrate understanding, application, and its relationship to the conservation of matter.

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Clarification 4: Instruction includes analyzing the photosynthesis equation to explain conservation of matter and transformation of energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using conceptual, graphical, and mathematical models to represent photosynthesis and the movement of matter and energy through the process. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations, investigations, and evidence to explain the inputs, outputs, and products of photosynthesis. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.2 Identify the stages of photosynthesis.

Benchmark Clarifications:

Clarification 1: Instruction includes light-dependent reactions and light-independent reactions (also referred to as dark reactions or the Calvin Cycle).

Clarification 2: Instruction includes that the products of light-dependent reactions provide energy and reduce power for light-independent reactions.

Clarification 3: Instruction includes using models and representations to describe relationships between light-dependent and light-independent reactions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.3 Explain light-dependent reactions in photosynthesis.

Benchmark Clarifications:

Clarification 1: Instruction includes that light-dependent reactions use energy from sunlight to produce oxygen and convert ADP and NADP+ into the energy carriers ATP and NADPH.

Clarification 2: Instruction includes that light-dependent reactions take place in the thylakoid membranes of chloroplasts.

Clarification 3: Instruction includes analyzing models and diagrams to trace the movement of energy and matter through light-dependent reactions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes analyzing observations and evidence used to explain the production of oxygen, ATP, and NADPH during light-dependent reactions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.4 Explain light-independent reactions in photosynthesis.

Benchmark Clarifications:

Clarification 1: Instruction includes that ATP and NADPH produced during the light-dependent reactions are used in the Calvin Cycle to produce high-energy sugars.

Clarification 2: Instruction includes that light-independent reactions take place in the stroma of the chloroplasts.

Clarification 3: Instruction includes using models and diagrams to trace the movement of carbon through the Calvin Cycle. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using observations and evidence to explain how carbon dioxide is incorporated into organic molecules during photosynthesis. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.5 Predict the rate of photosynthesis based on the intensity of light, temperature, or concentration of carbon dioxide.

Benchmark Clarifications:

Clarification 1: Instruction includes analyzing limiting factors affecting photosynthesis.

Clarification 2: Instruction includes interpreting graphs and datasets to determine relationships between photosynthetic rate and environmental variables. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using models to predict photosynthetic responses under changing environmental conditions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes using observations, investigations, and evidence to explain how environmental changes affect photosynthetic rate. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.6 Defend the importance of photosynthesis and describe its role in supporting life on Earth.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of photosynthesis in producing food for organisms that depend on others for their nutrition.

Clarification 2: Instruction includes the role of photosynthesis in synthesizing oxygen by replacing carbon dioxide in the atmosphere.

Clarification 3: Instruction includes that photosynthesis provides the biological foundation for most food webs and contributes to global carbon cycling.

Clarification 4: Instruction includes evaluating evidence that supports the role of photosynthesis in sustaining ecosystems and atmospheric oxygen concentrations. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes examining historical developments related to photosynthesis and how scientific explanations of energy transformation in living systems changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.7 Describe the chemosynthetic process by which specific microorganisms prepare food (glucose) using inorganic substances without sunlight.

Benchmark Clarifications:

Clarification 1: Instruction includes the reactants of chemosynthesis: Carbon dioxide (CO_2), Hydrogen sulfide (H_2S), and Oxygen (O_2).

Clarification 2: Instruction includes the products of chemosynthesis: Glucose ($C_6H_{12}O_6$), Sulfur (S), and Water (H_2O).

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Clarification 3: Instruction includes comparing photosynthesis and chemosynthesis as mechanisms for converting energy into organic molecules.

Clarification 4: Instruction includes using models and representations to explain the flow of matter and energy during chemosynthesis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence used to explain chemosynthesis in microorganisms living in environments without sunlight. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.2.8 Defend the importance of chemosynthesis and describe its role to sustain life on Earth.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of chemosynthesis as the basis of the marine food chain sustaining shrimp, tubeworms, clams, crabs, fish, and octopods.

Clarification 2: Instruction includes the role of chemosynthesis in volcanic caves where sunlight is absent.

Clarification 3: Instruction includes the role of chemosynthesis in sustaining life in extreme environments such as hydrothermal vents in deep-subsurface ecosystems where oxygen is insufficient or absent.

Clarification 4: Instruction includes comparing ecosystem productivity supported by photosynthesis and chemosynthesis using quantitative and graphical evidence. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating ecological models that demonstrate the role of chemosynthesis in sustaining ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating observations and scientific evidence that support the role of chemosynthesis in sustaining ecosystems where sunlight is absent. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to photosynthesis, chemosynthesis, and ecosystem energy sources and how scientific

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explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3 Explain how cells extract energy from food through aerobic pathways including glycolysis, pyruvate oxidation, the citric acid cycle, the electron transport chain, and fermentation; and how adenosine triphosphate (ATP) functions as the cell's usable form of energy.

SC.912.CB.3.1 Describe how the process of cellular respiration releases energy from food in the presence of oxygen.

Benchmark Clarifications:

Clarification 1: Instruction includes that oxygen plus glucose yields carbon dioxide, water, and energy.

Clarification 2: Instruction includes the four main stages of the cellular respiration process: glycolysis, pyruvate oxidation, the citric acid cycle (Krebs Cycle), and electron transport chain (oxidative phosphorylation).

Clarification 3: Instruction includes the use of the chemical formula for cellular respiration to demonstrate understanding, application, and its relationship to the conservation of matter.

Clarification 4: Instruction includes analyzing the cellular respiration equation to explain conservation of matter and transformation of energy. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using chemical equations and pathway models to represent energy transformations and conservation of matter during cellular respiration. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations, investigations, and evidence to explain the inputs, outputs, and products of cellular respiration. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 7: Instruction includes examining historical developments related to cellular respiration and how scientific explanations of biological energy transformation changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.2 Recognize the role of adenosine triphosphate (ATP) as the energy currency of a cell.

Benchmark Clarifications:

Clarification 1: Instruction includes the relationship between adenosine triphosphate (ATP) and adenosine diphosphate (ADP) as energy is transferred.

Clarification 2: Instruction includes the role of ATP within the electron transport chain.

Clarification 3: Instruction includes that ATP stores energy in chemical bonds and releases usable energy when converted to ADP.

Clarification 4: Instruction includes analyzing energy-transfer representations and quantitative data related to ATP production and use. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using models and representations to explain ATP cycling between ATP and ADP. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.3 Explain the breakdown of glucose through the process of glycolysis.

Benchmark Clarifications:

Clarification 1: Instruction includes the breakdown of glucose into 2 pyruvates with a net gain of 2 ATP molecules and 2 nicotinamide adenine dinucleotides (NADH).

Clarification 2: Instruction includes that NADH is a coenzyme that can transfer electrons.

Clarification 3: Instruction includes analyzing ATP and NADH production data associated with glycolysis. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes using pathway models and representations to trace the movement of matter and energy during glycolysis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using observations and evidence to explain the products and outcomes of glycolysis. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.4 Explain the conversion of pyruvate in the presence of oxygen.

Benchmark Clarifications:

Clarification 1: Instruction includes that in eukaryotes pyruvate oxidation takes place in the mitochondria.

Clarification 2: Instruction includes that pyruvate is converted into acetyl-CoA and carbon dioxide is released.

Clarification 3: Instruction includes analyzing carbon dioxide production and energy-transfer data associated with pyruvate oxidation. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using pathway models to explain the conversion of pyruvate into acetyl-CoA. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.5 Explain the citric acid cycle (Krebs Cycle).

Benchmark Clarifications:

Clarification 1: Instruction includes that the rate of the cycle is controlled by ATP concentration; when there is more ATP available, the rate slows down and when there is less ATP, the rate increases.

Clarification 2: Instruction includes the citric acid cycle as the second pathway in cellular respiration and is considered an aerobic pathway.

Clarification 3: Instruction includes each turn of the citric acid cycle provides a net gain of carbon dioxide (CO_2), 1 ATP, 3 NADH and 1 $FADH_2$.

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Clarification 4: Instruction includes that acetyl-CoA is further broken down, producing electron carriers and releasing carbon dioxide.

Clarification 5: Instruction includes analyzing ATP production data and rate-limiting conditions affecting the citric acid cycle. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using pathway models and representations to explain the movement of matter and energy through the citric acid cycle. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using observations and evidence to explain the production of ATP, NADH, $FADH_2$, and carbon dioxide during the citric acid cycle. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.6 Explain the electron transport chain.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of ATP synthase and its relationship to ADP and ATP.

Clarification 2: Instruction includes that the electron transport chain is the final stage of aerobic respiration.

Clarification 3: Instruction includes that electrons carried by NADH and $FADH_2$ provide energy used to create a proton gradient across the inner mitochondrial membrane.

Clarification 4: Instruction includes that ATP synthase uses the proton gradient to produce ATP.

Clarification 5: Instruction includes analyzing ATP production data associated with oxidative phosphorylation. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using models and representations to explain electron transport, proton movement, and ATP production. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.3.7 Locate where the electron transport chain functions within the mitochondria.

Benchmark Clarifications:

Clarification 1: Instruction includes that the electron transport chain is located in the inner mitochondrial membrane.

Clarification 2: Instruction includes that the inner mitochondrial membrane is folded many times (cristae) to increase the surface area of the electron transport chain components.

Clarification 3: Instruction includes analyzing how membrane surface area influences ATP production. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using models and diagrams to relate mitochondrial structure to cellular respiration function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.8 Analyze the process of generating energy in the absence of oxygen (fermentation).

Benchmark Clarifications:

Clarification 1: Instruction includes comparing ATP production in fermentation and aerobic respiration.

Clarification 2: Instruction includes interpreting data related to oxygen availability and energy production. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using models and representations to compare fermentation and aerobic respiration pathways. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using observations and evidence to explain how fermentation supports ATP production when oxygen is unavailable. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.9 Describe the process of alcoholic fermentation.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of yeast within alcoholic fermentation.

Clarification 2: Instruction includes that alcoholic fermentation produces ethanol, carbon dioxide, and regenerates NAD^+ for continued glycolysis.

Clarification 3: Instruction includes using pathway models to explain alcoholic fermentation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence from fermentation investigations and datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.3.10 Describe the process of lactic acid fermentation.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of lactic acid in human body systems.

Clarification 2: Instruction includes that lactic acid fermentation regenerates NAD^+ allowing glycolysis to continue in the absence of sufficient oxygen.

Clarification 3: Instruction includes that lactic acid fermentation occurs in certain microorganisms and in muscle cells under low-oxygen conditions.

Clarification 4: Instruction includes using pathway models to explain lactic acid fermentation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations, investigations, and physiological data related to lactic acid fermentation. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4 Explain how cell-size limitations create the need for division and how G1, S, and G2 stages of the cell cycle prepare prokaryotic and eukaryotic cells for accurate and efficient division.

SC.912.CB.4.1 Recognize the limitations of cell size.

Benchmark Clarifications:

Clarification 1: Instruction includes that the larger a cell becomes the more demands it places on its DNA.

Clarification 2: Instruction includes that a larger cell is less efficient in moving wastes and nutrients across the cell membrane.

Clarification 3: Instruction includes that cell size is limited by the relationship between surface area and volume.

Clarification 4: Instruction includes interpreting graphical and quantitative relationships between cell size, surface area, and volume. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence and observations used to explain how increasing cell size affects transport efficiency and cellular function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.2 Relate the ratio of surface area to volume of a cell.

Benchmark Clarifications:

Clarification 1: Instruction includes using the ratio of surface area to volume to see how the size of a cell's surface area grows compared to its volume.

Clarification 2: Instruction includes calculating and interpreting surface area-to-volume ratios using mathematical models. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using models and representations to explain how surface area-to-volume ratios influence cellular transport and cell size limitations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence used to explain the relationship between surface area, volume, and cellular efficiency. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.3 Describe the process of binary fission.

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Benchmark Clarifications:

Clarification 1: Instruction includes the steps of cell division in unicellular organisms: DNA replication, cell growth, segregation of DNA, and cytokinesis.

Clarification 2: Instruction includes that binary fission is the primary mode of reproduction for many bacteria such as Escherichia coli (E. coli).

Clarification 3: Instruction includes that some organelles such as mitochondria and chloroplasts reproduce using binary fission.

Clarification 4: Instruction includes using models and diagrams to explain the sequence of events in binary fission. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations and evidence used to explain binary fission in prokaryotic organisms. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to cells, microorganisms, and reproduction and how scientific explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.4 Recall that the cell cycle is the process in which a cell grows, prepares for division, and divides to form two daughter cells.

Benchmark Clarifications:

Clarification 1: Instruction includes both the prokaryotic and eukaryotic cell cycle.

Clarification 2: Instruction includes that the cell cycle maintains growth, repair, and reproduction in living organisms.

Clarification 3: Instruction includes using models and representations to identify major stages of the cell cycle. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.5 Explain the four phases of the eukaryotic cell cycle.

Example: The period of time associated with the cell cycle for skin cells and large intestinal cells in a human being.

Benchmark Clarifications:

Clarification 1: Instruction includes that the duration specific to the length of each phase of the cell cycle and the duration of the entire cell cycle varies depending on the type of cell.

Clarification 2: Instruction includes analyzing graphical representations of cell cycle duration among different cell types. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using models and diagrams to identify and explain phases of the eukaryotic cell cycle. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence used to compare cell cycle duration among different cell types. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.6 Analyze the phase where a cell prepares for division known as interphase.

Benchmark Clarifications:

Clarification 1: Instruction includes that interphase consists of three stages: Gap 1 (G1), Synthesis (S), and Gap 2 (G2).

Clarification 2: Instruction includes that most of a cell's life cycle occurs during interphase.

Clarification 3: Instruction includes using models and representations to explain the roles of G1, S, and G2 in preparing cells for division. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.7 Explain the cell growth, or Gap 1 (G1), phase of interphase.

Benchmark Clarifications:

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Clarification 1: Instruction includes that in this phase cells increase in size and synthesize new proteins and organelles.

Clarification 2: Instruction includes that cells perform normal cellular activities while preparing for DNA replication.

Clarification 3: Instruction includes analyzing observations and evidence used to explain cellular growth and organelle production during G1. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.8 Explain the DNA replication, or Synthesis (S), phase of interphase.

Benchmark Clarifications:

Clarification 1: Instruction includes that new DNA is synthesized when the chromosomes are replicated to ensure that each daughter cell receives an identical set of genetic information.

Clarification 2: Instruction includes that the cell at the end of the Synthesis (S) phase contains twice as much DNA as it did at the beginning.

Clarification 3: Instruction includes analyzing graphical and quantitative representations showing changes in DNA content during the cell cycle. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using models and representations to explain chromosome replication and DNA duplication during S phase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence used to explain DNA replication and the maintenance of genetic continuity. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.4.9 Explain the preparation for cell division, or Gap 2 (G2), phase of interphase.

Benchmark Clarifications:

Clarification 1: Instruction includes that many of the organelles and molecules required for cell division are produced in this phase.

Clarification 2: Instruction includes that cells continue to grow and prepare structures and molecules necessary for division.

Clarification 3: Instruction includes that cells monitor DNA replication and prepare for mitosis during G2.

Clarification 4: Instruction includes using models and representations to explain cellular preparation for division during G2. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5 Explain how DNA is replicated during S-phase and how mitosis, cytokinesis, and cell cycle regulatory mechanisms ensure accurate division and maintain healthy cells.

SC.912.CB.5.1 Describe the process by which a cell makes an exact copy of its DNA before cell division.

Benchmark Clarifications:

Clarification 1: Instruction includes DNA replication within mitosis and meiosis.

Clarification 2: Instruction includes that in eukaryotic cells this process occurs during the Synthesis (S) phase of the cell cycle.

Clarification 3: Instruction includes that DNA replication ensures each daughter cell receives the same genetic information.

Clarification 4: Instruction includes using models and representations to explain DNA replication prior to cell division. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.2 Describe DNA replication and explain the steps necessary for the development of a new DNA molecule.

Benchmark Clarifications:

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Clarification 1: Instruction includes that DNA replication occurs in the following order: unwinding, complementary base parring, and joining which results in two identical DNA molecules each with one old strand and one new strand of DNA.

Clarification 2: Instruction includes the important enzymes required for DNA replication: helicase, DNA polymerase, and ligase.

Clarification 3: Instruction includes using molecular models to explain DNA replication processes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing observations and evidence used to explain DNA replication and semiconservative inheritance. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes examining historical developments related to DNA structure and replication and how scientific explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.3 Illustrate the directionality of DNA replication.

Benchmark Clarifications:

Clarification 1: Instruction includes that during DNA replication the strands of DNA are antiparallel as one runs 5’→3’ and the other runs 3’→5’.

Clarification 2: Instruction includes that replication occurs in the 5’ to 3’ direction on the new strand.

Clarification 3: Instruction includes using molecular models to illustrate antiparallel strands and DNA synthesis in the 5'→3' direction. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing diagrams and molecular representations to explain DNA replication directionality. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.5.4 Identify the phases of mitosis that occur in the production of two identical cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the phases of mitosis: prophase, metaphase, anaphase, and telophase.

Clarification 2: Instruction includes that mitosis results in two genetically identical nuclei.

Clarification 3: Instruction includes using models and diagrams to identify the phases of mitosis and the major events occurring during each phase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.5 Analyze prophase, the first phase of mitosis.

Benchmark Clarifications:

Clarification 1: Instruction includes that during prophase chromosomes condense, spindle fibers form, and nuclear envelope begins to break down.

Clarification 2: Instruction includes the function of centromeres in relation to the replicated DNA.

Clarification 3: Instruction includes that each DNA strand in the duplicated chromosome is called a chromatid.

Clarification 4: Instruction includes paired structures which attach to spindle fibers and extend from a region called the centrosome are called centrioles.

Clarification 5: Instruction includes that plant cells lack centrioles and organize spindles directly from their centrosome region.

Clarification 6: Instruction includes using models and representations to analyze chromosome organization and spindle formation during prophase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes analyzing observations and microscopic evidence used to identify prophase. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.5.6 Analyze metaphase, the second phase of mitosis.

Benchmark Clarifications:

Clarification 1: Instruction includes that the centromeres of the duplicated chromosomes line up across the center of the cell at the metaphase plate (cell's equator).

Clarification 2: Instruction includes that spindle fibers attach the centromere of each chromosome to the two poles of the spindle.

Clarification 3: Instruction includes using models and representations to explain chromosome alignment and spindle attachment during metaphase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing observations and microscopic evidence used to identify metaphase. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.7 Analyze anaphase, the third phase of mitosis.

Benchmark Clarifications:

Clarification 1: Instruction includes that sister chromatids separate and move toward opposite poles of the cell along spindle fibers.

Clarification 2: Instruction includes using models and representations to explain chromosome movement during anaphase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing observations and microscopic evidence used to identify anaphase. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.8 Analyze telophase, the fourth phase of mitosis.

Benchmark Clarifications:

Clarification 1: Instruction includes nuclear envelopes reform around separated chromosomes and chromosomes decondense.

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Clarification 2: Instruction includes using models and representations to explain nuclear reformation and chromosome decondensation during telophase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing observations and microscopic evidence used to identify telophase. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.9 Explain cytokinesis that follows mitosis and completes the cell cycle.

Benchmark Clarifications:

Clarification 1: Instruction includes the differences of cytokinesis in plant and animal cells.

Clarification 2: Instruction includes that a cell plate is formed during cytokinesis in plant cells.

Clarification 3: Instruction includes using models and diagrams to compare cytokinesis in plant and animal cells. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing observations and microscopic evidence used to identify cytokinesis in plant and animal cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.10 Relate regulatory proteins with control of the cell cycle.

Benchmark Clarifications:

Clarification 1: Instruction includes regulatory proteins found both inside and outside of the cell.

Clarification 2: Instruction includes cyclins that regulate the timing of the cell cycle in eukaryotic cells.

Clarification 3: Instruction includes growth factors that stimulate the growth and division of cells.

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Clarification 4: Instruction includes analyzing graphical and quantitative data related to cell cycle regulation and checkpoint activity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using regulatory pathway models to predict effects of changes in cell-cycle control. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating observations and evidence used to explain how regulatory proteins influence progression through the cell cycle. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to cell cycle regulation, regulatory proteins, and cancer biology and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.5.11 Analyze the cellular processes that work together to maintain tissue health, remove damaged cells, and protect the organism.

Benchmark Clarifications:

Clarification 1: Instruction includes apoptosis, autophagy, and phagocytosis.

Clarification 2: Instruction includes analyzing data and scientific evidence used to evaluate cellular maintenance and protection mechanisms. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using models and representations to explain relationships among apoptosis, autophagy, phagocytosis, and tissue health. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating evidence describing how apoptosis, autophagy, and phagocytosis contribute to organism health. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.CB.6 Explain how DNA replication errors and environmental factors alter genetic information, how cells repair or regulate these changes, and how mutations, carcinogens, and ionizing radiation can affect inheritance, cellular processes, disease, and uncontrolled cell growth.

SC.912.CB.6.1 Explain the causes of mutations that can occur during DNA replication.

Benchmark Clarifications:

Clarification 1: Instruction includes spontaneous, random mistakes that can occur during replication.

Clarification 2: Instruction includes the induced mutations that are caused by external factors such as radiation or chemicals.

Clarification 3: Instruction includes analyzing mutation frequency data and environmental influences on mutation occurrence. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using observations and evidence to distinguish spontaneous mutations from environmentally induced mutations. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.2 Distinguish the potential consequences of mutations resulting from DNA replication errors.

Benchmark Clarifications:

Clarification 1: Instruction includes that there are neutral mutations that have no effect on the living organism.

Clarification 2: Instruction includes that there are beneficial mutations which can lead to evolution and adaptation.

Clarification 3: Instruction includes that there are harmful mutations which may cause genetic disorders or contribute to cancer.

Clarification 4: Instruction includes analyzing models and representations to predict the effects of mutations on biological systems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes using evidence to evaluate the effects of mutations on cellular function, organism health, and population variation. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.3 Explain how the DNA replication process is regulated.

Benchmark Clarifications:

Clarification 1: Instruction includes that DNA polymerase acts as a proofreader to correct most errors that occur during the replication process.

Clarification 2: Instruction includes additional repair systems that can fix mistakes after replication.

Clarification 3: Instruction includes that despite these systems some errors persist which can lead to genetic variation.

Clarification 4: Instruction includes using models and representations to explain proofreading and DNA repair mechanisms. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating evidence demonstrating the effectiveness of DNA repair systems in maintaining genetic stability. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to DNA replication, mutation, and DNA repair mechanisms and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.4 Predict the outcome of uncontrolled cell growth.

Benchmark Clarifications:

Clarification 1: Instruction includes when uncontrolled cell growth results in cancer and when uncontrolled cell growth does not result in cancer.

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Clarification 2: Instruction includes analyzing quantitative data associated with abnormal cell growth and cell-cycle regulation. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using models and evidence to predict outcomes of abnormal cell-cycle regulation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating observations and evidence used to distinguish controlled growth, noncancerous growth, and cancerous growth. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.5 Explain the outcome of uncontrolled cell growth that results in cancer.

Benchmark Clarifications:

Clarification 1: Instruction includes cancer occurs when uncontrolled cell growth is combined with other changes such as loss of normal cell cycle regulation, ability to invade surrounding tissues, and the potential to metastasize or spread to distant sites.

Clarification 2: Instruction includes that plants can develop tumors, but they usually do not metastasize because plant cells are fixed in rigid cell walls.

Clarification 3: Instruction includes that animals are most prone to cancer because of mobile cells and complex tissues.

Clarification 4: Instruction includes using models and representations to explain relationships among mutations, cell-cycle regulation, and cancer development. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating scientific evidence connecting mutations, cell-cycle disruption, and cancer development. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.6 Assess the possible noncancerous outcomes of uncontrolled cell growth.

Benchmark Clarifications:

Clarification 1: Instruction includes when uncontrolled, noncancerous cell growth occurs in animals it could result in: benign tumors, increased cell number (hyperplasia), increased cell size (hypertrophy), polyps, and cysts.

Clarification 2: Instruction includes that regenerative growth has a clear stop signal while uncontrolled, benign growth lacks feedback control.

Clarification 3: Instruction includes when uncontrolled, noncancerous cell growth occurs in plants it could result in: galls, callous formation, increased cell number (hyperplasia), and increased cell size (hypertrophy).

Clarification 4: Instruction includes using models and representations to compare mechanisms of benign and malignant growth. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes comparing evidence used to distinguish noncancerous growth from cancerous growth. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.7 Explain any substance or agent that can cause or promote cancer.

Benchmark Clarifications:

Clarification 1: Instruction includes that carcinogens cause or promote cancer typically by damaging DNA and disrupting normal cell function.

Clarification 2: Instruction includes chemical, physical, and biological agents that can contribute to cancer development.

Clarification 3: Instruction includes analyzing epidemiological and experimental data used to investigate carcinogens. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating evidence linking carcinogen exposure and cancer risk. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.8 Distinguish chemical, physical and biological carcinogens.

Benchmark Clarifications:

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Clarification 1: Instruction includes chemical carcinogens such as tobacco smoke and asbestos.

Clarification 2: Instruction includes physical carcinogens such as ultraviolet radiation and ionizing radiation.

Clarification 3: Instruction includes biological carcinogens such as viruses and other disease-causing agents associated with cancer development.

Clarification 4: Instruction includes comparing mechanisms by which different classes of carcinogens contribute to cancer risk.

Clarification 5: Instruction includes analyzing scientific evidence used to classify substances and agents as carcinogens. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.9 Explain the mechanisms found in carcinogens that result in the development of cancer.

Benchmark Clarifications:

Clarification 1: Instruction includes that carcinogens can cause DNA mutations by generating oxidative stress, causing DNA strand breaks, and forming DNA adducts.

Clarification 2: Instruction includes that carcinogens may impair DNA repair mechanisms or disrupt cell-cycle checkpoints, allowing mutated cells to survive and multiply.

Clarification 3: Instruction includes analyzing quantitative and epidemiological data associated with carcinogen exposure and cancer risk. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using models and representations to explain how carcinogens influence mutation rates, DNA repair systems, and cell-cycle control. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating scientific evidence used to explain carcinogen-induced cancer development. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes examining historical developments related to mutations, carcinogens, cancer biology, and the mechanisms of cancer development and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.6.10 Analyze the effects of ionizing radiation on DNA, cellular processes, inheritance, and disease.

Example: Evaluate biological responses to increasing radiation exposure.

Example: Analyze relationships among radiation exposure, mutation, and cancer risk.

Benchmark Clarifications:

Clarification 1: Instruction includes DNA strand breaks, chromosomal abnormalities, mutation mechanisms, and radiation-induced genetic variation.

Clarification 2: Instruction includes cellular responses to radiation exposure, including DNA repair mechanisms, cell-cycle regulation, apoptosis, and mutation accumulation.

Clarification 3: Instruction includes relationships among radiation exposure, mutation rates, cancer development, inherited genetic changes, and disease risk.

Clarification 4: Instruction includes analyzing quantitative data and exposure-response relationships associated with radiation-induced biological effects. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using models and representations to explain how ionizing radiation affects DNA, cellular processes, inheritance, and disease outcomes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating scientific evidence used to investigate relationships among radiation exposure, genetic changes, and disease. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to radiation biology, mutation research, cancer biology, and scientific understanding of radiation effects on living systems. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.7 Explain the purpose of meiosis, describe how its sequential phases produce genetically unique haploid cells, and distinguish these processes from mitosis.

SC.912.CB.7.1 Recognize the role of meiosis in living things.

Benchmark Clarifications:

Clarification 1: Instruction includes that the process of meiosis occurs in eukaryotic cells and not in prokaryotic cells because of the presence of a nucleus.

Clarification 2: Instruction includes that meiosis is a process to produce gametes and only takes place in sexually reproducing organism/s: animals, plants, fungi, and some protists.

Clarification 3: Instruction includes that in male animals' gametes are called sperm and in some plants pollen grains contain haploid (n) sperm cells.

Clarification 4: Instruction includes that in female animals generally only one of the cells produced by meiosis is an egg.

SC.912.CB.7.2 Describe how the process of meiosis provides for genetic variation.

Benchmark Clarifications:

Clarification 1: Instruction includes that meiosis produces gametes (sperm and egg cells) in sexually reproducing organisms to maintain chromosome number across generations.

Clarification 2: Instruction includes that diploid (2n) cells of most adult organisms contain two complete sets of inherited chromosomes and two complete sets of genes.

Clarification 3: Instruction includes that the process of meiosis reduces the chromosome number by half creating haploid (n) cells from a diploid (2n) cell.

Clarification 4: Instruction includes that the result of meiosis is four genetically unique haploid (n) daughter cells.

Clarification 5: Instruction includes using chromosome models and diagrams to explain mechanisms that generate genetic variation. using chromosome models and diagrams to explain mechanisms that generate genetic variation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes analyzing chromosome evidence and cellular observations used to explain crossing over and independent assortment. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.7.3 Identify the phases of meiosis that occur in the production of four haploid (n) cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that the process of meiosis starts with diploid (2n) cells and ends with haploid (n) cells.

Clarification 2: Instruction includes meiosis I and meiosis II as sequential divisions that reduce chromosome number and produce genetically unique haploid cells.

Clarification 3: Instruction includes using models and diagrams to identify phases of meiosis and chromosome behavior during each phase. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.7.4 Describe the process of interphase I of meiosis I.

Benchmark Clarifications:

Clarification 1: Instruction includes that during this phase the cell grows in size, the organelles replicate, and normal metabolic activities occur.

Clarification 2: Instruction includes that during this phase the DNA is replicated and each chromosome forms two sister chromatids joined at a centromere.

SC.912.CB.7.5 Explain the preparation of homologous chromosomes for separation and genetic recombination during prophase I of meiosis I.

Benchmark Clarifications:

Clarification 1: Instruction includes the important events that occur during this phase: chromosomes condense, homologous chromosomes pair up and form tetrads (synapsis), crossing over, nuclear envelope breakdown and spindle formation.

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SC.912.CB.7.6 Explain the positioning homologous chromosome pairs (tetrads) for proper segregation during metaphase I of meiosis I.

Benchmark Clarifications:

Clarification 1: Instruction includes the important events that occur during this phase: tetrads line up along metaphase plate (cell's equator), spindle fibers attach to the centromeres of each homologous chromosome, and independent assortment occurs.

Clarification 2: Instruction includes that independent assortment is a fundamental principle of genetics that states that alleles for different traits segregate independently of one another during the formation of gametes.

SC.912.CB.7.7 Explain the separation of homologous chromosomes during anaphase I of meiosis I.

Benchmark Clarifications:

Clarification 1: Instruction includes the important events that occur during this phase: spindle fibers shorten, the homologs detach from each other (chiasmata break), sister chromatids remain attached, and the cell now has a mix of maternal and paternal chromosomes at opposite poles.

SC.912.CB.7.8 Explain the separation of two haploid (n) daughter cells during telophase I of meiosis I.

Benchmark Clarifications:

Clarification 1: Instruction includes the important events that occur during this phase: chromosomes reach the poles and nuclear envelopes reform.

SC.912.CB.7.9 Explain the division of cytoplasm and resulting daughter cells that occur during cytokinesis at the conclusion of meiosis I.

Benchmark Clarifications:

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Clarification 1: Instruction includes that each resulting cell is haploid (n), but the chromosomes are still duplicated (sister chromatids).

Clarification 2: Instruction includes that the two resulting cells are genetically different from each other and from the original parent cell due to crossing over and independent assortment.

Clarification 3: Instruction includes the differences of cytokinesis in plant and animal cells.

Clarification 4: Instruction includes that a cell plate is formed during cytokinesis in plant cells.

SC.912.CB.7.10 Examine interkinesis the short resting phase that occurs between meiosis I and meiosis II.

Benchmark Clarifications:

Clarification 1: Instruction includes that during this phase there is no DNA replication, and the chromosomes remain duplicated (two sister chromatids).

Clarification 2: Instruction includes that in animal cells, centrosomes duplicate to prepare for spindle formation in meiosis II.

SC.912.CB.7.11 Explain the differences between prophase II and prophase I of meiosis.

Benchmark Clarifications:

Clarification 1: Instruction includes the differences in prophase II: occurs in haploid (n) cells with chromosomes that have already been duplicated, synapsis or crossing over do not occur, and the process is much shorter and simpler than prophase I.

SC.912.CB.7.12 Analyze the process of meiosis II.

Benchmark Clarifications:

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Clarification 1: Instruction includes the phases of meiosis II: prophase II, metaphase II, anaphase II and telophase II.

Clarification 2: Instruction includes that cytokinesis occurs at the conclusion of meiosis II and produces four haploid (n) daughter cells.

Clarification 3: Instruction includes that meiosis II separates sister chromatids in a manner similar to mitosis while maintaining the haploid chromosome number.

Clarification 4: Instruction includes using chromosome models and diagrams to explain chromosome movement during meiosis II. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing cellular observations used to identify stages of meiosis II and resulting daughter cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.7.13 Differentiate the processes and products of mitosis and meiosis.

Benchmark Clarifications:

Clarification 1: Instruction includes that mitosis produces genetically similar cells used for growth, repair, and asexual reproduction, while meiosis produces haploid gametes used in sexual reproduction.

Clarification 2: Instruction includes that meiosis occurs in two divisions, produces 4 haploid (n) cells, and results in genetic variation.

Clarification 3: Instruction includes that mitosis occurs in one division, produces 2 identical diploid (2n) cells, and results in no genetic variation.

Clarification 4: Instruction includes comparing quantitative and structural differences between mitosis and meiosis using models and data. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations, cellular evidence, and chromosome models to distinguish the processes and products of mitosis and meiosis. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to cell division, chromosome behavior, meiosis, and inheritance and how scientific explanations

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have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.7.14 Analyze how errors during meiosis influence chromosome number and inheritance.

Benchmark Clarifications:

Clarification 1: Instruction includes nondisjunction, aneuploidy, trisomy, monosomy, and chromosomal abnormalities.

SC.912.CB.8 Explain how fertilization leads to the development of a new organism and how gene linkage and recombination influence inherited traits.

SC.912.CB.8.1 Predict the results of the fertilization of a female gamete.

Benchmark Clarifications:

Clarification 1: Instruction includes that a fertilized female gamete (zygote) contains a combination of genetic material from both parents.

Clarification 2: Instruction includes that the zygote undergoes cell division by mitosis and eventually forms a new organism.

Clarification 3: Instruction includes that the female gamete is called an egg in animals and an egg cell in some plants.

Clarification 4: Instruction includes that the haploid (n) gamete cells become a diploid (2n) cell through the process of fertilization.

Clarification 5: Instruction includes using models and representations to explain how fertilization restores the diploid chromosome number and combines genetic material from two parents. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing chromosome models and evidence to explain inheritance of parental genetic information following fertilization. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.8.2 Explain the development of a zygote into an organism.

Benchmark Clarifications:

Clarification 1: Instruction includes the stages of development: cleavage, blastula, gastrulation, and organogenesis.

Clarification 2: Instruction includes that gastrulation includes the formation of three germ layers: ectoderm, mesoderm, and endoderm.

Clarification 3: Instruction includes the processes involved in the development: differentiation, growth, and morphogenesis.

Clarification 4: Instruction includes using developmental models and representations to explain cleavage, blastula formation, gastrulation, and organogenesis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations and evidence used to explain growth, differentiation, and morphogenesis during development. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.8.3 Explain how genes that are close together on the same chromosome tend to be inherited together because they are physically linked.

Benchmark Clarifications:

Clarification 1: Instruction includes that gene linkage occurs when genes located on the same chromosome tend to be inherited together, modifying the principle of independent assortment for linked genes.

Clarification 2: Instruction includes that gene linkage demonstrated that genes located on the same chromosome do not always assort independently and helped explain observed inheritance patterns.

Clarification 3: Instruction includes analyzing inheritance data to determine the effects of genetic linkage. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes using chromosome models and inheritance diagrams to explain genetic linkage and patterns of inheritance. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing experimental evidence used to explain genetic linkage and chromosome behavior. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to chromosome theory, genetic linkage, and inheritance and how scientific explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.8.4 Explain how the further apart two genes are the more likely a crossover will occur between them.

Benchmark Clarifications:

Clarification 1: Instruction includes that crossing over frequency is used to measure gene distance in map units.

Clarification 2: Instruction includes that gene mapping uses recombination rates to figure out relative positions of genes.

Clarification 3: Instruction includes that recombination creates new allele combinations.

Clarification 4: Instruction includes calculating recombination frequencies and interpreting gene maps. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using chromosome and gene-mapping models to explain relationships among gene location, recombination frequency, and crossing over. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing experimental evidence used to determine recombination frequencies and construct gene maps. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes examining historical developments related to genetic mapping, recombination, and chromosome theory and how scientific explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.9 Explain how cells communicate through multiple signaling pathways and how receptors, transduction, and amplification coordinate cellular functions.

SC.912.CB.9.1 Identify the connection between cell signaling and the complexity of living things.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of cells in the coordination of activities to maintain homeostasis and respond to changes in their environment.

Clarification 2: Instruction includes the importance of communication for processes like growth, development, immune response, and reproduction.

Clarification 3: Instruction includes using systems models to explain how cell signaling contributes to organization and complexity in living systems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using examples and evidence to explain how communication among cells supports coordinated functions in multicellular organisms. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.2 Explain intracellular signal transduction as a series of chemical reactions that activate and coordinate cellular responses.

Benchmark Clarifications:

Clarification 1: Instruction includes that signaling molecules are mostly hydrophilic and are unable to directly cross the cell membrane (plasma membrane).

Clarification 2: Instruction includes the possibility for smaller signal molecules to diffuse across the plasma barrier and bind to intracellular receptors inside the target cell in the cytosol or the nucleus.

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Clarification 3: Instruction includes signaling pathway models to explain how signals are transmitted from receptors to cellular targets. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing experimental evidence used to explain intracellular signaling pathways. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.3 Identify the four types of cell signaling pathways.

Benchmark Clarifications:

Clarification 1: Instruction includes that the type of cell signal is based on the distance the cell signal travels to reach its target.

Clarification 2: Instruction includes paracrine, endocrine, autocrine, and direct-contact signaling pathways.

Clarification 3: Instruction includes comparing signaling pathways based on signaling distance, target cells, and biological function using models and diagrams. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.4 Explain paracrine signaling.

Example: Describe the pathway of cell signaling which occurs during the transmission of impulses across synapses in nerve cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that paracrine signaling occurs in cells that are close to each other and act locally within a short region by diffusing to its neighbor through the extracellular environment to reach its target.

Clarification 2: Instruction includes that paracrine signals usually elicit quick responses that last for a short period of time.

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Clarification 3: Instruction includes using pathway models to explain paracrine signaling and local cellular responses. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing examples and evidence demonstrating local cell-to-cell communication. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.5 Explain endocrine signaling.

Benchmark Clarifications:

Clarification 1: Instruction includes that endocrine signaling is produced by specialized cells that release their signals into the bloodstream carrying them to target cells present in the distant parts of the body.

Clarification 2: Instruction includes how endocrine glands in humans, such as the hypothalamus, pituitary, pancreas, thyroid, and gonads, produce hormones and function by endocrine signaling.

Clarification 3: Instruction includes using signaling models to explain the movement of hormones from endocrine glands to target cells. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating evidence relating hormone signaling to cellular and organismal responses. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.6 Explain autocrine signaling.

Benchmark Clarifications:

Clarification 1: Instruction includes that autocrine signaling occurs when a cell releases a signaling molecule that binds to receptors on the same cell.

Clarification 2: Instruction includes the occurrence of autocrine signaling during the early developmental stage of an organism to ensure that cells develop into correct tissues and assume correct functions.

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Clarification 3: Instruction includes how autocrine signaling regulates pain sensation, inflammatory responses, and programmed cell death (apoptosis) in the infected or cancerous cell through signaling to itself.

Clarification 4: Instruction includes using signaling pathway models to explain autocrine signaling and self-regulation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence related to autocrine signaling in development, immune responses, and cellular regulation. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.7 Analyze the stages of cell signaling.

Benchmark Clarifications:

Clarification 1: Instruction includes the stages of reception, transduction, and response.

Clarification 2: Instruction includes an analysis of each stage at a molecular level.

Clarification 3: Instruction includes using signaling pathway models to explain reception, transduction, and response. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing experimental evidence used to explain receptor activation, signal transduction, and cellular responses. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.8 Describe the types of receptors involved in cell signaling.

Benchmark Clarifications:

Clarification 1: Instruction includes membrane receptors and intracellular receptors.

Clarification 2: Instruction includes a description of water-soluble signals such as peptides.

Clarification 3: Instruction includes a description of lipid-soluble signals such as steroid hormones.

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Clarification 4: Instruction includes using molecular and cellular models to compare membrane receptors and intracellular receptors. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence used to determine receptor structure and function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.9 Explain the process of signal amplification in cellular communication.

Benchmark Clarifications:

Clarification 1: Instruction includes the flow of biochemical reactions leading to a larger cellular response.

Clarification 2: Instruction includes examples of signal amplification such as insulin signaling for glucose uptake, neurotransmitter signaling in nerve cells, and plant hormones like auxin for growth.

Clarification 3: Instruction includes analyzing qualitative and quantitative representations of amplification pathways to explain how small signals can produce large cellular responses. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing amplification cascades using pathway diagrams and conceptual models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating evidence demonstrating signal amplification in biological systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.9.10 Examine how disruptions in signaling can lead to disease.

Benchmark Clarifications:

Clarification 1: Instruction includes the mechanisms of cell signaling and their direct connection to diseases such as diabetes, cancer, and autoimmune disorders.

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Clarification 2: Instruction includes analyzing biological and clinical data used to evaluate relationships between signaling pathways and disease. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using signaling pathway models to explain how disruptions in communication can alter cellular and organismal function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating evidence linking signaling disruptions to disease outcomes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes examining historical developments related to cell signaling, receptors, hormones, and signal transduction and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.10 Explain how genetic information is inherited, expressed, and investigated across generations using patterns of inheritance, variation in offspring, and modern genetic technologies.

SC.912.CB.10.1 Identify that genetic information is stored in deoxyribonucleic acid (DNA) and organized into genes and chromosomes.

Benchmark Clarifications:

Clarification 1: Instruction includes that deoxyribonucleic acid (DNA) is the molecule that carries hereditary information.

Clarification 2: Instruction includes genes as segments on deoxyribonucleic acid (DNA) located on chromosomes.

Clarification 3: Instruction includes that chromosomes are inherited from parents.

Clarification 4: Instruction includes using models and representations to explain relationships among DNA, genes, and chromosomes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes analyzing observations and evidence used to explain how hereditary information is organized and inherited. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to DNA, genes, chromosomes, and heredity and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.10.2 Describe how genetic information is passed from parents to offspring.

Benchmark Clarifications:

Clarification 1: Instruction includes meiosis and fertilization as processes of inheritance.

Clarification 2: Instruction includes that offspring inherit one allele for each gene from each parent.

Clarification 3: Instruction includes using chromosome models and inheritance diagrams to explain the transmission of genetic information from parents to offspring. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing inheritance evidence to explain how alleles are transmitted through meiosis and fertilization. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.10.3 Explain patterns of inheritance using Mendelian genetics.

Benchmark Clarifications:

Clarification 1: Instruction includes dominant and recessive traits.

Clarification 2: Instruction includes homozygous and heterozygous genotypes.

Clarification 3: Instruction includes using Punnett squares and probability models to predict inheritance patterns. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes using genetic models and inheritance diagrams to explain dominant and recessive inheritance patterns. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing inheritance evidence and genetic data to explain Mendelian patterns of inheritance. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to Mendelian genetics and inheritance and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.10.4 Explain how genetic variation occurs among offspring.

Benchmark Clarifications:

Clarification 1: Instruction includes independent assortment and crossing over.

Clarification 2: Instruction includes random fertilization as a source of variation.

Clarification 3: Instruction includes that independent assortment, crossing over, and random fertilization generate unique combinations of alleles in offspring.

Clarification 4: Instruction includes analyzing probability and inheritance data associated with genetic variation. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using chromosome models to explain mechanisms that generate genetic variation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing genetic evidence used to explain variation among offspring. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.10.5 Explain the role of genetic variation within populations.

Benchmark Clarifications:

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Clarification 1: Instruction includes phenotypic variation resulting from genotypes.

Clarification 2: Instruction includes variation as a foundation for population change over time.

Clarification 3: Instruction includes analyzing population-level data to explain the importance of genetic variation. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using population and inheritance models to explain relationships among genetic variation, phenotypic variation, and population change. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating evidence demonstrating the importance of genetic variation within populations. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to heredity, population genetics, and genetic variation and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.10.6 Analyze how biotechnology tools are used to isolate, analyze, compare, and identify genetic information.

Example: Compare DNA profiles from different samples.

Example: Interpret electrophoresis results to identify genetic similarities and differences.

Benchmark Clarifications:

Clarification 1: Instruction includes gel electrophoresis, DNA fingerprinting, DNA sequencing, polymerase chain reaction (PCR), and the interpretation of DNA banding patterns.

Clarification 2: Instruction includes applications of genetic technologies in scientific research, medicine, agriculture, and forensic investigations.

Clarification 3: Instruction includes analyzing genetic data generated by biotechnology tools to identify patterns, relationships, and genetic similarities or differences. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.CB.10.7 Analyze how allele frequencies and genotype frequencies change within populations over time.

Benchmark Clarifications:

Clarification 1: Instruction includes Hardy-Weinberg equilibrium, mutation, migration, genetic drift, natural selection, and nonrandom mating.

SC.912.CB.10.8 Analyze inheritance patterns that do not follow simple Mendelian relationships.

Benchmark Clarifications:

Clarification 1: Instruction includes incomplete dominance, codominance, multiple alleles, sex-linked inheritance, and polygenic inheritance.

SC.912.CB.10.9 Analyze genomic data to investigate genetic relationships, variation, and biological traits.

Benchmark Clarifications:

Clarification 1: Instruction includes genome sequencing, comparative genomics, genetic databases, and bioinformatics.

SC.912.CB.11 Explain how genetic information and environmental conditions interact to influence the expression of traits in living organisms and how genetic information can be modified and applied through biotechnology.

SC.912.CB.11.1 Explain the relationship between genotype and phenotype.

Benchmark Clarifications:

Clarification 1: Instruction includes a genotype as the genetic makeup of a living organism.

Clarification 2: Instruction includes a phenotype as the observable characteristics of a living organism.

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Clarification 3: Instruction includes that phenotypes result from the expression of genes and may be influenced by environmental conditions.

Clarification 4: Instruction includes using models and representations to explain relationships between genotype and phenotype. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations and evidence used to explain how genotypes contribute to observable traits. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.11.2 Describe how environmental conditions influence gene expression.

Benchmark Clarifications:

Clarification 1: Instruction includes environmental factors such as temperature, nutrition, light, and chemical exposure.

Clarification 2: Instruction includes that an environment can influence gene expression without changing the deoxyribonucleic acid (DNA) of a living organism.

Clarification 3: Instruction includes that environmental factors can alter the timing, location, or amount of gene expression.

Clarification 4: Instruction includes using models and representations to explain how environmental conditions influence gene expression. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing biological evidence demonstrating environmental influences on gene expression. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.11.3 Explain traits that are influenced by both genetics and environment.

Example: Analyze three real-world examples, human height, human skin pigmentation, and plant growth, to explain how genes establish a potential range for traits while environmental conditions can enhance or limit trait expression. Using short case studies, data sets, or images, identifying the genetic contribution, the environmental factor, and the

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resulting observable trait, then construct a cause-and-effect explanation connecting genetics, environment, and phenotype.

Benchmark Clarifications:

Clarification 1: Instruction includes how an environment may enhance or limit genetic potential.

Clarification 2: Instruction includes analyzing graphical and quantitative data to evaluate relationships among genotype, environmental conditions, and phenotype. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using conceptual and biological models to explain how genetic and environmental factors influence trait expression. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence from case studies, datasets, or investigations to explain interactions between genetics and environmental conditions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.11.4 Explain the regulation of gene expression within cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that not all genes are active at the same time or in all cells.

Clarification 2: Instruction includes both internal and external regulatory signals.

Clarification 3: Instruction includes that different cell types express different sets of genes despite containing the same DNA.

Clarification 4: Instruction includes that gene regulation contributes to cell specialization and organism development.

Clarification 5: Instruction includes using models and representations to explain how internal and external signals regulate gene expression. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes analyzing evidence used to explain patterns of gene expression in different cell types. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.11.5 Explain how genetic and environmental interactions influence survival and reproduction within populations of living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes how genetic and environmental interactions affect the survival and reproductive success of living organisms.

Clarification 2: Instruction includes how these interactions influence changes in population characteristics over time.

Clarification 3: Instruction includes analyzing population-level and quantitative data to evaluate how genetic and environmental interactions influence survival and reproductive success. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using models and biological evidence to predict how environmental changes may influence survival and reproductive success. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating biological evidence used to explain relationships among environmental conditions, genetic variation, survival, and reproduction. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to heredity, gene expression, environmental influences on traits, and population change and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.CB.11.6 Analyze how biotechnology techniques modify genetic information to alter organism traits and biological functions.

Example: Investigate genetically modified crops.

Example: Evaluate biomedical applications of genetic engineering.

Benchmark Clarifications:

Clarification 1: Instruction includes recombinant DNA, gene insertion, gene deletion, gene editing, and transgenic organisms.

Clarification 2: Instruction includes evaluating scientific evidence associated with genetically modified organisms in agriculture, medicine, and research.

SC.912.CB.11.7 Evaluate the use of gene-editing technologies in medicine, agriculture, and scientific research.

Benchmark Clarifications:

Clarification 1: Instruction includes CRISPR-Cas systems, targeted DNA modification, therapeutic applications, and ethical considerations.

Clarification 2: Instruction includes evaluating benefits, limitations, risks, and ethical considerations associated with gene-editing technologies.

SC.912.CB.11.8 Analyze how living cells and microorganisms are used to produce proteins and other biologically important compounds.

Benchmark Clarifications:

Clarification 1: Instruction includes insulin production, therapeutic proteins, vaccines, industrial enzymes, and microbial production systems.

Clarification 2: Instruction includes recombinant DNA technologies used to produce biological products.

Clarification 3: Instruction includes biomanufacturing and large-scale microbial production systems.

SC.912.CB.11.9 Analyze how epigenetic mechanisms influence gene expression and phenotype.

Benchmark Clarifications:

Clarification 1: Instruction includes DNA methylation, histone modification, environmental influences, and regulation without DNA sequence change.

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Proposed DRAFT Standards

The Science of Plants

How plant cells build and support whole organisms, capture and use energy, grow and reproduce, interact with their environments, and shape the ecosystems they sustain.

Grades 9-12

SC.912.P.1 Explain the structures and functions unique to plant cells, including cell walls, plasmodesmata, cytoskeletal components, membranes, and organelles, and describe how these structures support plant growth, transport, communication, protection, and cellular organization.

SC.912.P.1.1 Identify structures unique to plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes structures unique to plant cells including the cell wall, chloroplasts, large central vacuole, plasmodesmata, and specialized plastids.

Clarification 2: Instruction includes plastids such as chloroplasts, chromoplasts, leucoplasts, and amyloplasts.

Clarification 3: Instruction includes relationships between plant-cell structures and their primary functions.

SC.912.P.1.2 Describe the structure and composition of plant cell walls.

Benchmark Clarifications:

Clarification 1: Instruction includes cellulose as a primary structural component of plant cell walls.

Clarification 2: Instruction includes primary and secondary cell walls.

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Clarification 3: Instruction includes structural differences between primary and secondary cell walls.

SC.912.P.1.3 Explain how plant cell walls support plant growth, protection, and water balance.

Benchmark Clarifications:

Clarification 1: Instruction includes structural support, maintenance of cell shape, and plant rigidity.

Clarification 2: Instruction includes protection from mechanical damage and pathogens.

Clarification 3: Instruction includes resistance to expansion caused by water entering cells through osmosis.

Clarification 4: Instruction includes turgor pressure and its relationship to cell-wall function.

Clarification 5: Instruction includes the role of cell walls in regulating the direction of cell expansion during growth.

SC.912.P.1.4 Illustrate the structure of the plasma membrane in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the phospholipid bilayer consisting of hydrophilic heads and hydrophobic tails.

Clarification 2: Instruction includes membrane proteins associated with transport and communication.

SC.912.P.1.5 Explain how substances move into and out of plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes diffusion, osmosis, facilitated diffusion, and active transport.

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Clarification 2: Instruction includes movement of water, ions, sugars, gases, and other substances across the plasma membrane.

Clarification 3: Instruction includes relationships between membrane transport and cellular homeostasis.

Clarification 4: Instruction includes using membrane and transport models to explain movement of substances across plant-cell membranes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.1.6 Describe the structure of plasmodesmata.

Benchmark Clarifications:

Clarification 1: Instruction includes that plasmodesmata are channels connecting adjacent plant cells.

Clarification 2: Instruction includes structural components including the plasma membrane, cytoplasmic sleeve, and desmotubule.

SC.912.P.1.7 Explain the role of plasmodesmata in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes transport of ions, sugars, amino acids, proteins, RNA, and signaling molecules.

Clarification 2: Instruction includes communication related to growth, development, and defense responses.

Clarification 3: Instruction includes the symplastic pathway.

Clarification 4: Instruction includes that plasmodesmata can be dynamically regulated through opening and closing.

Clarification 5: Instruction includes comparisons between plasmodesmata in plants and gap junctions in animal cells.

SC.912.P.1.8 Identify the major components of the plant cytoskeleton.

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Benchmark Clarifications:

Clarification 1: Instruction includes microfilaments, microtubules, and intermediate filament-like proteins.

Clarification 2: Instruction includes the protein composition of major cytoskeletal structures.

SC.912.P.1.9 Explain the functions of the plant cytoskeleton.

Benchmark Clarifications:

Clarification 1: Instruction includes maintenance of cell organization and structural support.

Clarification 2: Instruction includes intracellular transport and organelle movement.

Clarification 3: Instruction includes cytoplasmic streaming.

Clarification 4: Instruction includes chromosome movement and spindle formation during cell division.

Clarification 5: Instruction includes responses to environmental stimuli such as light and gravity.

Clarification 6: Instruction includes using cellular models and representations to explain relationships among cytoskeletal organization, transport, growth, and cell division. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.2 Explain the structure and functions of the nucleus and nucleolus in plant cells, including their roles in storing genetic information, regulating cellular activities, and producing ribosomes.

SC.912.P.2.1 Describe the structure of the nucleus in a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the nucleus is surrounded by a double membrane called the nuclear envelope.

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Clarification 2: Instruction includes nuclear pores that regulate exchange of materials between the nucleus and cytoplasm.

Clarification 3: Instruction includes nucleoplasm as the fluid-filled region within the nucleus.

Clarification 4: Instruction includes chromatin as DNA associated with proteins that is contained within the nucleus.

SC.912.P.2.2 Explain the functions of the nucleus in a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the nucleus stores and protects genetic information.

Clarification 2: Instruction includes that the nucleus regulates cellular activities through control of gene expression.

Clarification 3: Instruction includes that nuclear pores allow regulated movement of molecules between the nucleus and cytoplasm.

Clarification 4: Instruction includes that the nuclear envelope contributes to maintenance of genetic integrity by protecting DNA and regulating molecular exchange.

Clarification 5: Instruction includes using cellular models to explain relationships among DNA, the nucleus, gene expression, and cellular function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.2.3 Describe the structure and composition of the nucleolus in a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the nucleolus is a dense region within the nucleus that is not surrounded by a membrane.

Clarification 2: Instruction includes that the nucleolus contains ribosomal RNA (rRNA), proteins, and DNA regions associated with ribosome production.

Clarification 3: Instruction includes that plant cells may contain one or more nucleoli within a nucleus.

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SC.912.P.2.4 Explain the function of the nucleolus in a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the nucleolus is the site of ribosomal RNA production.

Clarification 2: Instruction includes assembly of ribosomal subunits within the nucleolus.

Clarification 3: Instruction includes the role of ribosomes in protein synthesis and plant-cell function.

SC.912.P.3 Explain the structure and functions of cytoplasm in plant cells including its role in supporting organelles, facilitating biochemical reactions, and enabling the movement, storage, and distribution of molecules and ions.

SC.912.P.3.1 Describe the structure and composition of cytoplasm in a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes cytosol, organelles, and the cytoskeleton as major components associated with the cytoplasm.

Clarification 2: Instruction includes that cytoplasm is a gel-like material that surrounds organelles and provides an environment for cellular activities.

SC.912.P.3.2 Explain how the cytoplasm supports interactions among cellular structures in a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the cytoplasm provides a medium that supports communication and coordination among organelles.

Clarification 2: Instruction includes interactions among chloroplasts, mitochondria, vacuoles, and other organelles.

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SC.912.P.3.3 Identify the biochemical reactions that occur within the cytoplasm of a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes metabolic processes such as glycolysis and amino acid synthesis.

Clarification 2: Instruction includes that cytoplasmic reactions connect products of photosynthesis to cellular respiration and other metabolic pathways.

SC.912.P.3.4 Explain the role of cytoplasm in the movement and distribution of substances within a plant cell.

Benchmark Clarifications:

Clarification 1: Instruction includes transport and distribution of nutrients, ions, metabolites, and signaling molecules.

Clarification 2: Instruction includes relationships among intracellular transport, cell signaling, and cellular coordination.

Clarification 3: Instruction includes using cellular models to explain movement of substances within plant cells. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.4 Describe the structures and functions of plant-cell mitochondria and plastids, including chloroplasts, chromoplasts, amyloplasts, and leucoplasts; and explain how these organelles support energy transformation, photosynthesis, pigment production, storage, and cellular metabolism.

SC.912.P.4.1 Describe the structure of the mitochondria in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the outer membrane, inner membrane, cristae, and matrix of mitochondria.

Clarification 2: Instruction includes that mitochondria are surrounded by a double membrane.

Clarification 3: Instruction includes that folding of the inner membrane increases surface area within the mitochondrion.

SC.912.P.4.2 Explain the function of mitochondria in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that mitochondria carry out cellular respiration.

Clarification 2: Instruction includes that mitochondria convert energy stored in organic molecules into adenosine triphosphate (ATP).

Clarification 3: Instruction includes that cellular respiration provides energy for cellular processes within plant cells.

Clarification 4: Instruction includes using models to explain energy transformations during cellular respiration. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.4.3 Describe the structure of plastids in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes plastids such as chloroplasts, chromoplasts, leucoplasts, and amyloplasts.

Clarification 2: Instruction includes that plastids are surrounded by a double membrane.

Clarification 3: Instruction includes that some plastids may differentiate into other plastid types during plant growth and development.

Clarification 4: Instruction includes structural characteristics used to distinguish major plastid types.

SC.912.P.4.4 Explain the functions of plastids in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes chloroplasts as sites of photosynthesis.

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Clarification 2: Instruction includes chromoplasts as plastids that synthesize and store pigments.

Clarification 3: Instruction includes leucoplasts as plastids involved in storage and biosynthetic functions.

Clarification 4: Instruction includes amyloplasts as plastids that store starch and may function as gravity-sensing statoliths in root tissues.

Clarification 5: Instruction includes the roles of plastids in energy storage, pigment production, metabolism, and plant growth.

SC.912.P.4.5 Explain the role of chloroplasts in photosynthesis.

Benchmark Clarifications:

Clarification 1: Instruction includes chloroplast structures such as the outer membrane, inner membrane, thylakoids, grana, stroma, and chlorophyll.

Clarification 2: Instruction includes chlorophyll as the primary pigment that absorbs light energy for photosynthesis.

Clarification 3: Instruction includes that the light-dependent reactions occur within the thylakoid membranes and produce ATP and NADPH.

Clarification 4: Instruction includes that the light-independent reactions (Calvin cycle) occur within the stroma and use ATP and NADPH to produce carbohydrates.

Clarification 5: Instruction includes that chloroplasts convert light energy into chemical energy stored in organic molecules.

Clarification 6: Instruction includes using models to explain energy transformations and movement of matter during photosynthesis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.4.6 Explain the relationship between mitochondria and plastids in plant cells.

Benchmark Clarifications:

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Clarification 1: Instruction includes that chloroplasts produce organic molecules used by mitochondria during cellular respiration.

Clarification 2: Instruction includes that mitochondria release energy from organic molecules produced through photosynthesis.

Clarification 3: Instruction includes cycling of matter and transformation of energy between photosynthesis and cellular respiration.

Clarification 4: Instruction includes that chloroplasts and mitochondria contain DNA and ribosomes and perform some protein synthesis independently of the nucleus.

Clarification 5: Instruction includes distinguishing chloroplasts and mitochondria from the nucleus based on structure, genetic material, and cellular function.

Clarification 6: Instruction includes using systems models to explain relationships among photosynthesis, cellular respiration, and energy flow within plant cells. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.5 Describe the structures and functions of the large central vacuole and tonoplast in plant cells and explain how these structures support storage, transport, growth, turgor pressure, and cellular homeostasis.

SC.912.P.5.1 Describe the structure of the large central vacuole and tonoplast in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the large central vacuole as a membrane-bound compartment occupying much of the volume of many plant cells.

Clarification 2: Instruction includes the tonoplast as the selectively permeable membrane surrounding the vacuole.

Clarification 3: Instruction includes that the vacuole contains water, ions, nutrients, pigments, metabolites, and other dissolved substances.

Clarification 4: Instruction includes relationships between the vacuole, tonoplast, cytoplasm, and cell wall.

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SC.912.P.5.2 Explain the functions of the large central vacuole in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes storage of water, nutrients, pigments, metabolites, and defense compounds.

Clarification 2: Instruction includes isolation of wastes and potentially harmful substances from the cytoplasm.

Clarification 3: Instruction includes maintenance of turgor pressure that supports cell structure and helps prevent wilting.

Clarification 4: Instruction includes the role of vacuoles in cell enlargement and plant growth.

Clarification 5: Instruction includes maintenance of cellular pH, ion balance, and other homeostatic conditions.

SC.912.P.5.3 Explain the functions of the tonoplast in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes regulation of movement of water, ions, sugars, and other solutes between the cytoplasm and vacuole.

Clarification 2: Instruction includes maintenance of vacuolar pH and internal chemical conditions.

Clarification 3: Instruction includes regulation of cellular water balance and turgor pressure.

Clarification 4: Instruction includes transport processes that support storage, detoxification, and cellular homeostasis.

SC.912.P.5.4 Analyze how vacuoles and tonoplasts support plant growth, survival, and responses to environmental conditions.

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Benchmark Clarifications:

Clarification 1: Instruction includes relationships among vacuolar storage, water balance, plant growth, and drought tolerance.

Clarification 2: Instruction includes the role of vacuoles in defense against herbivores, pathogens, and environmental stressors.

Clarification 3: Instruction includes contributions of vacuolar pigments to coloration of flowers and fruits.

Clarification 4: Instruction includes how vacuoles and tonoplasts contribute to whole-plant homeostasis and survival in changing environments.

Clarification 5: Instruction includes using systems models to explain relationships among vacuolar transport, turgor pressure, plant growth, and environmental responses. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.6 Explain the structures and functions of the endoplasmic reticulum, Golgi apparatus, ribosomes, and peroxisomes in plant cells and describe how these organelles synthesize, modify, transport, and process molecules that support plant growth, metabolism, and cellular homeostasis.

SC.912.P.6.1 Describe the structure of the endoplasmic reticulum in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the endoplasmic reticulum as an interconnected network of membranous sacs (cisternae) and tubules that are continuous with the nuclear envelope.

Clarification 2: Instruction includes rough endoplasmic reticulum and smooth endoplasmic reticulum.

Clarification 3: Instruction includes the endoplasmic reticulum lumen enclosed by a single membrane.

Clarification 4: Instruction includes structural differences between rough and smooth endoplasmic reticulum.

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SC.912.P.6.2 Explain the functions of the endoplasmic reticulum in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that rough endoplasmic reticulum synthesizes, folds, and modifies proteins.

Clarification 2: Instruction includes proteins associated with membranes, secretion, cell-wall formation, defense responses, and other cellular functions.

Clarification 3: Instruction includes that smooth endoplasmic reticulum synthesizes lipids, detoxifies compounds, stores calcium, and produces materials used in cellular structures.

Clarification 4: Instruction includes transport of proteins and lipids from the endoplasmic reticulum to other cellular locations including the Golgi apparatus.

Clarification 5: Instruction includes contributions of the endoplasmic reticulum to growth, development, defense responses, and cellular homeostasis.

SC.912.P.6.3 Describe the structure of the Golgi apparatus in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the Golgi apparatus as a series of flattened membrane-bound sacs associated with transport vesicles.

Clarification 2: Instruction includes cis and trans regions associated with receiving and exporting cellular products.

Clarification 3: Instruction includes relationships between the Golgi apparatus and the endoplasmic reticulum.

SC.912.P.6.4 Explain the functions of the Golgi apparatus in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes modification, sorting, and packaging of proteins and lipids.

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Clarification 2: Instruction includes production of cell-wall polysaccharides.

Clarification 3: Instruction includes formation and transport of vesicles to membranes, vacuoles, and other cellular destinations.

Clarification 4: Instruction includes secretion of proteins, signaling molecules, and other cellular products.

Clarification 5: Instruction includes contributions of the Golgi apparatus to plant growth, transport, reproduction, defense, and environmental responses.

SC.912.P.6.5 Describe the structure of ribosomes in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes that ribosomes consist of large and small subunits composed of ribosomal RNA and proteins.

Clarification 2: Instruction includes ribosomes located freely within the cytoplasm and attached to the rough endoplasmic reticulum.

Clarification 3: Instruction includes structural differences between free and attached ribosomes.

SC.912.P.6.6 Explain the functions of ribosomes in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes protein synthesis through translation of messenger RNA (mRNA).

Clarification 2: Instruction includes that free ribosomes generally produce proteins used within the cell.

Clarification 3: Instruction includes that attached ribosomes generally produce proteins for membranes, secretion, and transport.

Clarification 4: Instruction includes proteins involved in photosynthesis, cellular respiration, transport, growth, defense, and cell-wall formation.

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SC.912.P.6.7 Describe the structure and functions of peroxisomes in plant cells.

Benchmark Clarifications:

Clarification 1: Instruction includes peroxisomes as membrane-bound organelles containing enzymes involved in oxidation reactions.

Clarification 2: Instruction includes detoxification of harmful compounds and breakdown of reactive oxygen species.

Clarification 3: Instruction includes roles in photorespiration.

Clarification 4: Instruction includes conversion of stored lipids to sugars during seed germination.

Clarification 5: Instruction includes contributions to nitrogen metabolism, stress responses, cellular homeostasis, and plant survival.

Clarification 6: Instruction includes using models to explain interactions among the endoplasmic reticulum, Golgi apparatus, ribosomes, and peroxisomes during synthesis, processing, transport, and regulation of cellular products. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.7 Classify plants into major groups including nonvascular plants, seedless vascular plants, gymnosperms, and angiosperms based on structural, reproductive, and life-cycle characteristics.

SC.912.P.7.1 Classify plants into major groups based on structural and reproductive characteristics.

Benchmark Clarifications:

Clarification 1: Instruction includes characteristics used in plant classification including vascular tissue, reproductive structures, seed production, flower production, fruit production, leaf characteristics, and growth form.

Clarification 2: Instruction includes classification of plants as nonvascular plants, seedless vascular plants, gymnosperms, and angiosperms.

Clarification 3: Instruction includes using classification frameworks, dichotomous keys, and cladograms to identify and classify plants. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.7.2 Explain the structural and reproductive characteristics of nonvascular plants.

Benchmark Clarifications:

Clarification 1: Instruction includes that nonvascular plants lack vascular tissue and transport materials primarily through diffusion and osmosis.

Clarification 2: Instruction includes simple plant body structures and adaptation to moist environments.

Clarification 3: Instruction includes alternation of generations involving gametophyte and sporophyte stages.

Clarification 4: Instruction includes that fertilization requires water.

SC.912.P.7.3 Explain the structural and reproductive characteristics of seedless vascular plants.

Benchmark Clarifications:

Clarification 1: Instruction includes vascular tissues including xylem and phloem.

Clarification 2: Instruction includes true roots, stems, and leaves.

Clarification 3: Instruction includes microphylls and megaphylls.

Clarification 4: Instruction includes alternation of generations involving gametophyte and sporophyte stages.

Clarification 5: Instruction includes that fertilization requires water.

SC.912.P.7.4 Compare nonvascular plants and seedless vascular plants.

Benchmark Clarifications:

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Clarification 1: Instruction includes similarities and differences in vascular tissues, transport mechanisms, structural complexity, and reproductive strategies.

Clarification 2: Instruction includes constructing explanations using evidence from plant structures and reproductive characteristics. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.7.5 Explain the structural and reproductive characteristics of gymnosperms.

Benchmark Clarifications:

Clarification 1: Instruction includes vascular tissues and true roots, stems, and leaves.

Clarification 2: Instruction includes seeds not enclosed within fruits.

Clarification 3: Instruction includes male and female cones.

Clarification 4: Instruction includes pollination primarily by wind.

Clarification 5: Instruction includes alternation of generations involving gametophyte and sporophyte stages.

SC.912.P.7.6 Explain the structural and reproductive characteristics of angiosperms.

Benchmark Clarifications:

Clarification 1: Instruction includes vascular tissues and true roots, stems, leaves, flowers, and fruits.

Clarification 2: Instruction includes seeds enclosed within fruits.

Clarification 3: Instruction includes double fertilization.

Clarification 4: Instruction includes pollination through biotic and abiotic mechanisms.

Clarification 5: Instruction includes the role of flowers in reproduction and fruits in seed dispersal.

Clarification 6: Instruction includes alternation of generations involving gametophyte and sporophyte stages.

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SC.912.P.7.7 Distinguish plant groups using structural, reproductive, and life-cycle characteristics.

Benchmark Clarifications:

Clarification 1: Instruction includes that all plants exhibit alternation of generations involving gametophyte and sporophyte stages.

Clarification 2: Instruction includes differences in dominant life-cycle stages among major plant groups.

Clarification 3: Instruction includes using structural, reproductive, and life-cycle evidence to classify plants and interpret evolutionary relationships.

Clarification 4: Instruction includes analyzing classification data and phylogenetic relationships among major plant groups. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.8 Describe the structures and functions of major plant organs and tissues, including roots, stems, leaves, flowers, seeds, fruits, dermal tissue, vascular tissue, ground tissue, and meristems; and explain how these components work together to support plant growth, transport, reproduction, and survival.

SC.912.P.8.1 Describe the functions of roots, stems, and leaves in plants.

Benchmark Clarifications:

Clarification 1: Instruction includes roots in anchorage, absorption of water and minerals, and storage.

Clarification 2: Instruction includes stems in support, transport, and storage.

Clarification 3: Instruction includes leaves in photosynthesis, gas exchange, and transpiration.

Clarification 4: Instruction includes interactions among roots, stems, and leaves that support plant survival.

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SC.912.P.8.2 Analyze the structures and functions of roots.

Benchmark Clarifications:

Clarification 1: Instruction includes root cap, apical meristem, root hairs, cortex, endodermis, Casparian strip, xylem, and phloem.

Clarification 2: Instruction includes absorption of water and minerals, anchorage, storage, and transport.

SC.912.P.8.3 Analyze the structures and functions of stems.

Benchmark Clarifications:

Clarification 1: Instruction includes nodes, internodes, vascular bundles, cortex, pith, cambium, and bark.

Clarification 2: Instruction includes support, transport, storage, and growth.

SC.912.P.8.4 Analyze the structures and functions of leaves.

Benchmark Clarifications:

Clarification 1: Instruction includes cuticle, epidermis, mesophyll, stomata, guard cells, and veins.

Clarification 2: Instruction includes photosynthesis, gas exchange, and transpiration.

Clarification 3: Instruction includes the roles of stomata and guard cells in regulating water loss and gas exchange.

SC.912.P.8.5 Analyze the structures and functions of flowers, seeds, and fruits.

Benchmark Clarifications:

Clarification 1: Instruction includes flower structures such as sepals, petals, stamens, and carpels (pistils).

Clarification 2: Instruction includes pollination, fertilization, and seed development.

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Clarification 3: Instruction includes seed structures such as seed coat, embryo, endosperm, and cotyledons.

Clarification 4: Instruction includes fruit structures such as exocarp, mesocarp, and endocarp.

Clarification 5: Instruction includes roles of flowers, seeds, and fruits in reproduction, protection, dormancy, and dispersal.

SC.912.P.8.6 Explain the roles of dermal, vascular, and ground tissues in plants.

Benchmark Clarifications:

Clarification 1: Instruction includes dermal tissue in protection, water conservation, absorption, secretion, and gas exchange.

Clarification 2: Instruction includes vascular tissue in transport and support.

Clarification 3: Instruction includes ground tissue in photosynthesis, storage, and support.

Clarification 4: Instruction includes relationships among tissue systems and organ function.

SC.912.P.8.7 Analyze the structures and functions of vascular tissues.

Benchmark Clarifications:

Clarification 1: Instruction includes xylem cells such as tracheids, vessel elements, fibers, and parenchyma.

Clarification 2: Instruction includes phloem cells such as sieve-tube elements, companion cells, fibers, and parenchyma.

Clarification 3: Instruction includes transport of water and minerals through xylem.

Clarification 4: Instruction includes transport of sugars and other organic molecules through phloem.

Clarification 5: Instruction includes vascular bundles, veins, and vascular cylinders.

SC.912.P.8.8 Analyze the structures and functions of ground tissues.

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Benchmark Clarifications:

Clarification 1: Instruction includes parenchyma, collenchyma, and sclerenchyma cells.

Clarification 2: Instruction includes relationships between cell type, structure, location, and function.

Clarification 3: Instruction includes photosynthesis, storage, and support functions of ground tissue.

SC.912.P.8.9 Explain the roles of meristems in plant growth.

Benchmark Clarifications:

Clarification 1: Instruction includes apical, lateral, and intercalary meristems.

Clarification 2: Instruction includes meristematic cells as sources of new cells.

Clarification 3: Instruction includes primary and secondary growth and associated meristems.

SC.912.P.8.10 Analyze the movement of water through plants.

Benchmark Clarifications:

Clarification 1: Instruction includes movement of water through roots, xylem, leaves, and the atmosphere.

Clarification 2: Instruction includes osmosis, cohesion, adhesion, and transpiration pull.

Clarification 3: Instruction includes interactions among root anatomy, vascular tissues, leaf structures, stomata, and guard cells.

Clarification 4: Instruction includes constructing and interpreting models of water movement through plants. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.P.9 Explain how photosynthesis, cellular respiration, transpiration, and hormone-regulated growth enable plant survival and productivity and how these processes contribute to energy flow, matter cycling, and ecosystem function.

SC.912.P.9.1 Explain how photosynthesis supports plant survival and ecosystem productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes that plants use light energy, water, and carbon dioxide to produce carbohydrates and oxygen.

Clarification 2: Instruction includes photosynthesis as the primary source of biomass and chemical energy in plants.

Clarification 3: Instruction includes contributions of photosynthesis to oxygen production, food webs, primary productivity, and the carbon cycle.

SC.912.P.9.2 Analyze how plant structures and adaptations influence photosynthesis.

Benchmark Clarifications:

Clarification 1: Instruction includes leaf morphology, venation, stomatal distribution, mesophyll tissues, and chloroplast distribution.

Clarification 2: Instruction includes physiological adaptations that maximize light capture and carbon dioxide uptake while minimizing water loss.

Clarification 3: Instruction includes chloroplast movement and responses to changing light conditions.

SC.912.P.9.3 Explain how transport systems support photosynthesis and plant function.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of xylem in transporting water and minerals from roots to photosynthetic tissues.

Clarification 2: Instruction includes the role of phloem in transporting carbohydrates and other organic molecules throughout the plant.

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Clarification 3: Instruction includes interactions among roots, stems, leaves, xylem, and phloem that support photosynthesis and growth.

SC.912.P.9.4 Explain how transpiration contributes to plant growth, transport, and survival.

Benchmark Clarifications:

Clarification 1: Instruction includes movement of water from roots through xylem to leaves and the atmosphere.

Clarification 2: Instruction includes transpiration pull, cohesion, adhesion, and water-potential relationships.

Clarification 3: Instruction includes the role of transpiration in mineral transport, cooling, and maintenance of turgor pressure.

Clarification 4: Instruction includes analyzing transpiration-rate data under different environmental conditions. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.9.5 Explain how plant hormones regulate growth and physiological responses.

Benchmark Clarifications:

Clarification 1: Instruction includes auxins, cytokinins, gibberellins, abscisic acid (ABA), ethylene, and brassinosteroids.

Clarification 2: Instruction includes regulation of growth, development, stress responses, dormancy, and environmental responses.

Clarification 3: Instruction includes interpreting experimental evidence describing hormone regulation of plant growth and physiology. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.9.6 Explain how cellular respiration supports plant survival and growth.

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Benchmark Clarifications:

Clarification 1: Instruction includes cellular respiration as the process that converts energy stored in organic molecules into adenosine triphosphate (ATP).

Clarification 2: Instruction includes cellular respiration in roots, stems, leaves, and other living plant tissues.

Clarification 3: Instruction includes that ATP supports water uptake, nutrient transport, growth, repair, reproduction, and cellular maintenance.

SC.912.P.9.7 Distinguish the roles of photosynthesis and cellular respiration in plant systems.

Benchmark Clarifications:

Clarification 1: Instruction includes photosynthesis as the process that captures and stores energy in organic molecules.

Clarification 2: Instruction includes cellular respiration as the process that releases energy stored in organic molecules.

Clarification 3: Instruction includes cycling of matter and transformation of energy between these processes.

Clarification 4: Instruction includes how interactions between photosynthesis and cellular respiration contribute to plant homeostasis and survival.

Clarification 5: Instruction includes systems models connecting photosynthesis, cellular respiration, growth, plant productivity, and ecosystem function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.9.8 Analyze plants as integrated biological systems.

Benchmark Clarifications:

Clarification 1: Instruction includes interactions among roots, stems, leaves, vascular tissues, and reproductive structures.

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Clarification 2: Instruction includes relationships among water uptake, mineral transport, photosynthesis, cellular respiration, growth, and reproduction.

Clarification 3: Instruction includes movement of matter and flow of energy through whole-plant systems.

Clarification 4: Instruction includes feedbacks among environmental conditions, physiological processes, and plant responses.

Clarification 5: Instruction includes constructing and interpreting systems models that explain how plant organs and physiological processes function together to maintain growth, reproduction, homeostasis, and survival. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.10 Explain how plants reproduce through asexual and sexual strategies and analyze how reproductive structures, developmental processes, and hormonal regulation contribute to plant survival, growth, and genetic diversity.

SC.912.P.10.1 Explain how plants reproduce through asexual and sexual strategies.

Benchmark Clarifications:

Clarification 1: Instruction includes reproductive structures, processes, and outcomes associated with asexual and sexual reproduction.

Clarification 2: Instruction includes that asexual reproduction produces genetically similar offspring while sexual reproduction produces genetically diverse offspring.

Clarification 3: Instruction includes advantages and disadvantages associated with both reproductive strategies.

SC.912.P.10.2 Explain mechanisms of asexual reproduction in plants.

Benchmark Clarifications:

Clarification 1: Instruction includes vegetative propagation, fragmentation, cuttings, grafting, layering, and tissue culture.

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Clarification 2: Instruction includes natural vegetative propagation through structures such as rhizomes, tubers, bulbs, corms, stolons, and leaves.

Clarification 3: Instruction includes artificial vegetative propagation techniques used in agriculture and horticulture.

Clarification 4: Instruction includes that asexual reproduction produces genetically identical offspring.

SC.912.P.10.3 Explain how plant structures support asexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of meristematic cells in cell division, regeneration, rooting, and vegetative growth.

Clarification 2: Instruction includes grafting as the joining of a scion and rootstock to produce a functional plant.

Clarification 3: Instruction includes that the upper portion of a grafted plant remains genetically identical to the source scion.

Clarification 4: Instruction includes the role of auxins and other growth regulators in rooting, regeneration, and graft formation.

SC.912.P.10.4 Explain the processes of sexual reproduction in plants.

Benchmark Clarifications:

Clarification 1: Instruction includes pollination, fertilization, seed formation, fruit development, seed dispersal, and germination.

Clarification 2: Instruction includes flower structures involved in reproduction including stamens, pistils, anthers, stigmas, ovaries, and ovules.

Clarification 3: Instruction includes self-pollination and cross-pollination.

Clarification 4: Instruction includes pollination agents such as wind, water, insects, birds, and other animals.

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Clarification 5: Instruction includes fertilization processes including pollen-tube growth, sperm-egg fusion, and double fertilization in angiosperms.

SC.912.P.10.5 Explain how seeds and fruits contribute to plant reproduction and survival.

Benchmark Clarifications:

Clarification 1: Instruction includes seed structures such as embryo, cotyledons, endosperm, and seed coat.

Clarification 2: Instruction includes requirements for germination including water, oxygen, and appropriate temperature conditions.

Clarification 3: Instruction includes development of fruits from ovaries following fertilization.

Clarification 4: Instruction includes seed-dispersal mechanisms including wind, water, animals, and mechanical ejection.

Clarification 5: Instruction includes how fruit development and seed dispersal reduce competition and increase survival.

SC.912.P.10.6 Explain how hormones regulate plant reproduction and development.

Benchmark Clarifications:

Clarification 1: Instruction includes auxins, gibberellins, cytokinins, ethylene, and abscisic acid (ABA).

Clarification 2: Instruction includes hormonal regulation of flowering, fruit development, seed dormancy, germination, and vegetative propagation.

Clarification 3: Instruction includes hormonal influences on both asexual and sexual reproductive processes.

Clarification 4: Instruction includes evaluating evidence describing hormonal regulation of plant reproduction and development. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.P.10.7 Compare asexual and sexual reproduction in plants.

Benchmark Clarifications:

Clarification 1: Instruction includes differences in reproductive structures and processes.

Clarification 2: Instruction includes differences in genetic variation among offspring.

Clarification 3: Instruction includes advantages and disadvantages of asexual reproduction, including rapid reproduction and limited genetic diversity.

Clarification 4: Instruction includes advantages and disadvantages of sexual reproduction, including increased genetic diversity and greater reproductive complexity.

Clarification 5: Instruction includes analyzing reproductive strategies in relation to environmental conditions, population survival, and adaptation.

Clarification 6: Instruction includes interpreting data and evidence comparing reproductive success and genetic variation among reproductive strategies. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.11 Explain how plants interact with their environment and other organisms, including their ecological roles, adaptations, symbiotic relationships, and responses to biotic and abiotic stressors.

SC.912.P.11.1 Explain the ecological roles of plants within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes plant contributions to energy flow, primary productivity, food webs, and biogeochemical cycles.

Clarification 2: Instruction includes plant influences on carbon cycling, oxygen production, biomass accumulation, and ecosystem stability.

Clarification 3: Instruction includes relationships among plant populations, communities, and ecosystem processes.

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SC.912.P.11.2 Explain how plant adaptations support survival in changing environments.

Benchmark Clarifications:

Clarification 1: Instruction includes structural, physiological, and behavioral adaptations that improve survival and reproduction.

Clarification 2: Instruction includes advanced adaptations such as CAM photosynthesis, carnivory, allelopathy, mimicry, and nitrogen-fixing symbioses.

Clarification 3: Instruction includes plant responses to biotic and abiotic stressors.

Clarification 4: Instruction includes relationships among environmental pressures, adaptation, and plant survival.

SC.912.P.11.3 Analyze interactions between plants and other organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes mutualism, competition, herbivory, parasitism, and commensalism.

Clarification 2: Instruction includes plant-to-plant interactions such as competition, allelopathy, facilitation, and signaling through volatile organic compounds.

Clarification 3: Instruction includes plant-animal interactions involving pollination, seed dispersal, herbivory, coevolution, and mutualistic relationships.

Clarification 4: Instruction includes how interactions influence population size, community composition, and ecosystem structure.

SC.912.P.11.4 Explain symbiotic relationships involving plants.

Benchmark Clarifications:

Clarification 1: Instruction includes mycorrhizal associations and endophytic relationships.

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Clarification 2: Instruction includes exchanges of nutrients, water, protection, and other benefits between symbiotic partners.

Clarification 3: Instruction includes ecological consequences resulting from the loss of one or more members of a symbiotic relationship.

Clarification 4: Instruction includes constructing explanations from evidence describing symbiotic interactions and ecosystem impacts. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.11.5 Analyze the roles of fungi and decomposition in supporting plant communities.

Benchmark Clarifications:

Clarification 1: Instruction includes nutrient cycling relationships among decomposers, fungi, soils, and plants.

Clarification 2: Instruction includes saprophytic fungi and decomposition processes.

Clarification 3: Instruction includes ecosystem consequences resulting from disruptions to decomposition or nutrient cycling.

Clarification 4: Instruction includes using systems models to explain interactions among fungi, decomposition, nutrient cycling, and plant productivity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.11.6 Analyze the effects of environmental stressors on plants.

Benchmark Clarifications:

Clarification 1: Instruction includes abiotic stressors such as drought, temperature extremes, salinity, pollution, and habitat alteration.

Clarification 2: Instruction includes biotic stressors such as pathogens, parasites, herbivores, and invasive species.

Clarification 3: Instruction includes air pollutants such as ozone, sulfur dioxide, nitrogen oxides, particulate matter, and acid rain.

Clarification 4: Instruction includes water and soil pollutants.

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Clarification 5: Instruction includes effects of stressors on photosynthesis, growth, reproduction, survival, and community composition.

SC.912.P.12 Explain how plants function as primary producers by capturing energy, converting it into biomass, and driving ecosystem productivity; and analyze the factors and human influences that affect plant production and ecosystem structure.

SC.912.P.12.1 Explain the role of plants as primary producers in ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes that plants capture solar energy through photosynthesis and convert it into chemical energy.

Clarification 2: Instruction includes that plants form the foundation of food webs and ecosystem energy flow.

Clarification 3: Instruction includes that primary production supports consumers, decomposers, and ecosystem stability.

Clarification 4: Instruction includes constructing explanations describing the role of plants in ecosystem energy flow and productivity. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.12.2 Explain how plants convert energy into biomass.

Benchmark Clarifications:

Clarification 1: Instruction includes biomass as the amount of organic material produced and stored by plants.

Clarification 2: Instruction includes that biomass represents stored chemical energy available to ecosystems.

Clarification 3: Instruction includes that plant biomass is commonly measured as dry mass per unit area.

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Clarification 4: Instruction includes relationships among photosynthesis, growth, carbon storage, and biomass accumulation.

SC.912.P.12.3 Analyze the importance of primary production in ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes that primary production determines the availability of energy across trophic levels.

Clarification 2: Instruction includes that primary production influences herbivore and predator populations.

Clarification 3: Instruction includes that primary production contributes to nutrient cycling, habitat formation, species interactions, and ecosystem stability.

SC.912.P.12.4 Identify factors that influence plant production and biomass.

Benchmark Clarifications:

Clarification 1: Instruction includes abiotic factors such as light, temperature, water availability, carbon dioxide concentration, nutrients, and soil conditions.

Clarification 2: Instruction includes biotic factors such as competition, herbivory, disease, symbiosis, and allelopathy.

Clarification 3: Instruction includes human-driven factors such as land-use change, pollution, fertilization, and resource management.

SC.912.P.12.5 Analyze how environmental factors influence plant production and ecosystem structure.

Benchmark Clarifications:

Clarification 1: Instruction includes effects of abiotic, biotic, and anthropogenic factors on biomass accumulation and primary productivity.

Clarification 2: Instruction includes ecosystem responses to changes in plant production.

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Clarification 3: Instruction includes relationships among plant productivity, biodiversity, population dynamics, and ecosystem stability.

SC.912.P.12.6 Calculate net primary production in ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes the ecological relationship: net primary production (NPP) = gross primary production (GPP) - respiration (R).

Clarification 2: Instruction includes net primary production (NPP) as energy remaining after plant respiration.

Clarification 3: Instruction includes gross primary production (GPP) as total energy captured through photosynthesis.

Clarification 4: Instruction includes respiration (R) as energy used for plant metabolism.

Clarification 5: Instruction includes interpretation of quantitative ecosystem productivity data.

Clarification 6: Instruction includes calculating and interpreting primary-productivity values. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.12.7 Compare ecosystem productivity using biomass and net primary production data.

Benchmark Clarifications:

Clarification 1: Instruction includes graphical and quantitative comparisons of biomass and productivity among ecosystems.

Clarification 2: Instruction includes relationships among climate, resource availability, biomass, and productivity.

Clarification 3: Instruction includes analysis of human influences on ecosystem productivity.

Clarification 4: Instruction includes interpreting datasets to evaluate differences in ecosystem productivity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.P.13 Explain the role of plants in the movement of essential elements through ecosystems, including how they drive the carbon, hydrologic, and nitrogen cycles through photosynthesis, transpiration, nutrient uptake, and interactions with other organisms.

SC.912.P.13.1 Explain the role of plants in biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes the carbon, hydrologic, and nitrogen cycles.

Clarification 2: Instruction includes plants as major pathways through which matter moves between the atmosphere, biosphere, hydrosphere, and geosphere.

Clarification 3: Instruction includes relationships among photosynthesis, transpiration, nutrient uptake, decomposition, and ecosystem processes.

SC.912.P.13.2 Explain the role of plants in the carbon and hydrologic cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes that plants remove carbon dioxide from the atmosphere through photosynthesis and incorporate carbon into plant biomass.

Clarification 2: Instruction includes movement of carbon through food webs, decomposition, and soil systems.

Clarification 3: Instruction includes plant uptake of water and movement of water through roots, stems, leaves, and the atmosphere.

Clarification 4: Instruction includes transpiration and its influence on atmospheric moisture, precipitation patterns, and hydrologic balance.

Clarification 5: Instruction includes connections between carbon storage, water movement, and ecosystem productivity.

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SC.912.P.13.3 Explain the role of plants in the nitrogen cycle.

Example: In Florida, crops such as peanuts and soybeans are planted in rotation to naturally improve soil nitrogen reducing the need for synthetic fertilizers and supporting agricultural and ecosystem health. Investigate how legume plants support nitrogen fixing bacteria by forming root nodules and supplying carbohydrates allowing atmospheric nitrogen to be converted into a usable form that sustains food webs.

Benchmark Clarifications:

Clarification 1: Instruction includes plant uptake of nitrate and ammonium from soils.

Clarification 2: Instruction includes that nitrogen uptake can be influenced by soil pH, oxygen availability, and microbial activity.

Clarification 3: Instruction includes the return of nitrogen to soils through decomposition and other biological processes.

Clarification 4: Instruction includes interactions between plants and nitrogen-fixing microorganisms.

Clarification 5: Instruction includes examples such as legumes that form root nodules containing nitrogen-fixing bacteria.

Clarification 6: Instruction includes plant influences on nitrogen transformations within ecosystems.

SC.912.P.13.4 Analyze how plants drive ecosystem cycling of matter.

Benchmark Clarifications:

Clarification 1: Instruction includes tracing movement of carbon, water, and nitrogen among organisms and environmental reservoirs.

Clarification 2: Instruction includes interactions among plants, microorganisms, soils, water, and the atmosphere.

Clarification 3: Instruction includes ecosystem consequences of changes in plant productivity or plant abundance.

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Clarification 4: Instruction includes constructing explanations and using systems models to describe movement of matter through carbon, hydrologic, and nitrogen cycles. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.14 Explain how structural, physiological, reproductive, and ecological adaptations enable plants to survive, grow, reproduce, and persist across diverse environments and long-term environmental change.

SC.912.P.14.1 Explain how structural adaptations enable plants to survive in different environments.

Benchmark Clarifications:

Clarification 1: Instruction includes structural adaptations of roots, stems, leaves, and reproductive structures.

Clarification 2: Instruction includes adaptations associated with deserts, grasslands, aquatic environments, temperate forests, tropical rainforests, and tundra habitats.

Clarification 3: Instruction includes relationships among environmental conditions and plant structural characteristics.

SC.912.P.14.2 Explain how physiological adaptations enable plants to survive environmental stresses.

Benchmark Clarifications:

Clarification 1: Instruction includes water conservation mechanisms, drought responses, temperature tolerance, salt tolerance, and chemical defenses.

Clarification 2: Instruction includes C3, C4, and CAM photosynthetic pathways.

Clarification 3: Instruction includes osmotic regulation and hormonal responses to environmental stress.

Clarification 4: Instruction includes relationships between physiological adaptations and resource availability.

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SC.912.P.14.3 Analyze how plants respond to environmental stimuli.

Benchmark Clarifications:

Clarification 1: Instruction includes phototropism, gravitropism, and thigmotropism.

Clarification 2: Instruction includes nastic movements.

Clarification 3: Instruction includes photoperiodism and circadian rhythms.

Clarification 4: Instruction includes how responses increase resource acquisition, survival, and reproductive success.

SC.912.P.14.4 Explain how reproductive adaptations increase plant survival and reproductive success.

Benchmark Clarifications:

Clarification 1: Instruction includes adaptations associated with flowers, seeds, fruits, pollen, and dispersal mechanisms.

Clarification 2: Instruction includes differences between wind and animal pollination strategies.

Clarification 3: Instruction includes clonal growth and other forms of vegetative reproduction.

Clarification 4: Instruction includes relationships between reproductive strategies and environmental conditions.

SC.912.P.14.5 Explain how ecological adaptations support plant survival and interactions with other organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes mutualistic relationships involving mycorrhizal fungi, nitrogen-fixing bacteria, and animals.

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Clarification 2: Instruction includes ecological benefits provided through these interactions.

Clarification 3: Instruction includes how biotic interactions influence plant fitness and survival.

SC.912.P.14.6 Analyze how plant populations adapt to long-term environmental conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes fire adaptations and succession-related adaptations.

Clarification 2: Instruction includes coevolution between plants and other organisms across generations.

Clarification 3: Instruction includes evolution of photosynthetic strategies such as C3, C4, and CAM pathways in response to environmental conditions.

Clarification 4: Instruction includes evidence supporting relationships among adaptation, natural selection, and environmental change.

Clarification 5: Instruction includes using models and evidence to explain how environmental conditions influence the distribution of plant adaptations through time and across ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.15 Explain how plants initiate, influence, and respond to ecological succession, including the roles of pioneer species, disturbance regimes, and plant resilience in shaping community development over time.

SC.912.P.15.1 Explain how plants influence ecological succession and community development.

Benchmark Clarifications:

Clarification 1: Instruction includes primary and secondary succession.

Clarification 2: Instruction includes changes in plant communities and ecosystem structure through time.

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Clarification 3: Instruction includes interactions among plants, soils, resources, and environmental conditions during succession.

Clarification 4: Instruction includes using succession models to explain and predict ecosystem change through time. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.15.2 Explain the role of pioneer species in ecological succession.

Benchmark Clarifications:

Clarification 1: Instruction includes pioneer species such as lichens, mosses, and early colonizing plants.

Clarification 2: Instruction includes physical and chemical weathering processes that contribute to soil formation.

Clarification 3: Instruction includes how pioneer species alter environmental conditions and facilitate establishment of later successional species.

SC.912.P.15.3 Analyze how disturbance regimes influence ecological succession.

Benchmark Clarifications:

Clarification 1: Instruction includes natural and anthropogenic disturbances that alter plant communities and ecosystem resources.

Clarification 2: Instruction includes disturbance characteristics including type, frequency, intensity, and spatial scale.

Clarification 3: Instruction includes how disturbances influence resource availability, competition, species composition, and succession pathways.

Clarification 4: Instruction includes relationships between disturbance patterns and plant adaptations that promote survival and recolonization.

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SC.912.P.15.4 Analyze how plant resilience influences ecosystem recovery following disturbance.

Benchmark Clarifications:

Clarification 1: Instruction includes plant resilience as the capacity to survive, regenerate, or recover following disturbance.

Clarification 2: Instruction includes relationships among resilience, succession, competition, and community stability.

Clarification 3: Instruction includes ecosystem recovery following fire, storms, flooding, drought, invasive species, or other disturbances.

Clarification 4: Instruction includes evaluating ecological recovery data following disturbance events. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes constructing explanations supported by evidence to describe recovery and succession following disturbance. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.16 Explain how plant populations grow, persist, and change over time by examining reproduction, recruitment, limiting factors, species interactions, carrying capacity, habitat loss, and ecological models that describe population and community dynamics.

SC.912.P.16.1 Explain factors that influence plant population growth and persistence.

Benchmark Clarifications:

Clarification 1: Instruction includes that a plant population consists of individuals of the same species living in the same area at the same time.

Clarification 2: Instruction includes relationships among reproduction, seed production, germination, seedling survival, and population growth.

Clarification 3: Instruction includes abiotic factors such as light, water, nutrients, temperature, and soil conditions.

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Clarification 4: Instruction includes biotic factors such as competition, herbivory, disease, and mutualistic interactions.

SC.912.P.16.2 Explain how limiting factors influence plant populations.

Benchmark Clarifications:

Clarification 1: Instruction includes limiting factors that affect growth, reproduction, survival, and distribution.

Clarification 2: Instruction includes resource availability, environmental conditions, and species interactions as limiting factors.

Clarification 3: Instruction includes relationships between limiting factors and population abundance.

SC.912.P.16.3 Relate carrying capacity to plant population dynamics.

Benchmark Clarifications:

Clarification 1: Instruction includes carrying capacity as the maximum population size that an environment can support over time.

Clarification 2: Instruction includes relationships among limiting factors, resource availability, and carrying capacity.

Clarification 3: Instruction includes graphical representations of population growth.

Clarification 4: Instruction includes exponential and logistic growth patterns.

SC.912.P.16.4 Explain interactions among plant species within communities.

Benchmark Clarifications:

Clarification 1: Instruction includes competition, mutualism, facilitation, herbivory, and parasitism.

Clarification 2: Instruction includes how species interactions influence population size, distribution, and community composition.

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Clarification 3: Instruction includes relationships between plant interactions and ecosystem structure.

SC.912.P.16.5 Analyze recruitment as a process that influences plant population change.

Benchmark Clarifications:

Clarification 1: Instruction includes recruitment as the addition of new individuals to a population.

Clarification 2: Instruction includes seed production, seed dispersal, seed-bank dynamics, germination, seedling establishment, and survival.

Clarification 3: Instruction includes how recruitment influences species abundance, succession, and community composition.

SC.912.P.16.6 Analyze ecological models of plant population and community dynamics.

Benchmark Clarifications:

Clarification 1: Instruction includes models of population growth, competition, succession, disturbance recovery, and recruitment.

Clarification 2: Instruction includes J-curve (exponential growth) and S-curve (logistic growth) models.

Clarification 3: Instruction includes comparing model predictions with observed population data.

Clarification 4: Instruction includes using qualitative and quantitative models to predict changes in plant populations and communities. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes interpretation of graphical population-growth data and carrying-capacity relationships. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.P.16.7 Analyze the effects of habitat loss on plant populations and communities.

Benchmark Clarifications:

Clarification 1: Instruction includes habitat destruction and fragmentation in forests, grasslands, wetlands, and other ecosystems.

Clarification 2: Instruction includes effects of habitat loss on population size, recruitment, genetic diversity, and species distribution.

Clarification 3: Instruction includes consequences for community composition and ecosystem function.

Clarification 4: Instruction includes analyzing spatial patterns of habitat fragmentation and population change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.17 Explain how invasive plant species spread, disrupt ecosystems, and alter ecological processes; and evaluate the human activities, environmental impacts, and management strategies associated with their introduction and control.

SC.912.P.17.1 Explain how invasive plant species spread and establish populations.

Benchmark Clarifications:

Clarification 1: Instruction includes pathways of spread through seed dispersal, vegetative reproduction, water movement, wildlife transport, and human activities.

Clarification 2: Instruction includes biological characteristics that contribute to successful establishment and expansion.

Clarification 3: Instruction includes the role of natural and human-mediated movement in introducing invasive plants to new habitats.

SC.912.P.17.2 Analyze the ecological impacts of invasive plant species.

Benchmark Clarifications:

Clarification 1: Instruction includes competition with native species for light, water, nutrients, and space.

Clarification 2: Instruction includes reductions in biodiversity through displacement of native plant communities.

Clarification 3: Instruction includes effects on habitat structure, food webs, and species interactions.

Clarification 4: Instruction includes impacts on soil characteristics, hydrologic processes, nutrient cycling, and ecosystem function.

Clarification 5: Instruction includes consequences for native animal populations when invasive plants alter food sources, nesting sites, or habitat availability.

SC.912.P.17.3 Analyze how invasive plant species influence ecosystem development and community change.

Benchmark Clarifications:

Clarification 1: Instruction includes effects on ecological succession and community composition.

Clarification 2: Instruction includes disruption of ecosystem recovery following disturbance.

Clarification 3: Instruction includes prevention of native species reestablishment and persistence.

Clarification 4: Instruction includes development of alternative stable communities dominated by invasive species.

Clarification 5: Instruction includes using ecological models to explain how invasive species alter succession, population dynamics, and ecosystem processes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.P.17.4 Evaluate strategies used to prevent and manage invasive plant species.

Benchmark Clarifications:

Clarification 1: Instruction includes prevention strategies such as monitoring, public education, regulation, and early detection.

Clarification 2: Instruction includes management strategies such as mechanical control, chemical control, biological control, and ecological restoration.

Clarification 3: Instruction includes advantages and limitations of different management approaches.

Clarification 4: Instruction includes evaluating management effectiveness using scientific evidence and ecological data. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes interpreting ecological data to assess invasive species impacts and management outcomes. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.18 Explain how anthropogenic activities affect plants by altering habitats, changing land and water use, introducing pollution, and protecting plant species through conservation efforts and environmental regulations.

SC.912.P.18.1 Explain how anthropogenic activities influence plant populations and communities.

Benchmark Clarifications:

Clarification 1: Instruction includes effects on plant abundance, species diversity, reproductive success, and population persistence.

Clarification 2: Instruction includes interactions among human activities, plant populations, and ecosystem processes.

Clarification 3: Instruction includes consequences for community composition and biodiversity.

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SC.912.P.18.2 Analyze how land-use practices affect plant ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes deforestation, land conversion, urbanization, agriculture, and habitat fragmentation.

Clarification 2: Instruction includes overgrazing, logging, mining, and crop-selection practices.

Clarification 3: Instruction includes effects on habitat availability, species distributions, ecosystem function, and biodiversity.

Clarification 4: Instruction includes changes in succession, productivity, and community structure resulting from land-use practices.

SC.912.P.18.3 Analyze how anthropogenic activities alter hydrologic conditions that affect plants.

Benchmark Clarifications:

Clarification 1: Instruction includes human influences on water availability, movement, and distribution.

Clarification 2: Instruction includes irrigation, water diversion, drainage, groundwater withdrawal, and land-cover change.

Clarification 3: Instruction includes effects on plant growth, reproduction, distribution, and ecosystem health.

SC.912.P.18.4 Examine sources of pollution that affect plants and ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes air, soil, and water pollutants.

Clarification 2: Instruction includes chemical contaminants, nutrient pollution, plastics, and other environmental pollutants.

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Clarification 3: Instruction includes pathways through which pollutants affect plant tissues, soils, water resources, and ecological processes.

SC.912.P.18.5 Analyze the effects of pollution on plant populations and ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes effects on plant growth, physiology, reproduction, survival, and community composition.

Clarification 2: Instruction includes consequences for biodiversity, ecosystem productivity, and ecosystem stability.

Clarification 3: Instruction includes interpretation of quantitative evidence describing pollution impacts on plants and ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.18.6 Evaluate conservation strategies used to protect plant species and ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes habitat protection, ecosystem restoration, seed banking, invasive-species management, sustainable land-use practices, and pollution reduction.

Clarification 2: Instruction includes environmental regulations designed to reduce pollution, conserve habitats, limit harmful practices, and protect biodiversity.

Clarification 3: Instruction includes evaluation of evidence describing the effectiveness of conservation and management strategies.

Clarification 4: Instruction includes constructing explanations supported by evidence to evaluate conservation efforts and environmental policies. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.P.19 Explain how plants sustain human populations by supplying essential resources such as food, atmospheric oxygen, medicinal compounds, and economic raw materials; describe how plant systems influence human communities by regulating environmental quality and supporting the conditions necessary for human life; and analyze how plant resources and plant systems are applied to address human needs.

SC.912.P.19.1 Explain how plants support human survival and well-being.

Benchmark Clarifications:

Clarification 1: Instruction includes food production and human nutrition.

Clarification 2: Instruction includes atmospheric oxygen production and carbon dioxide uptake.

Clarification 3: Instruction includes plant contributions to water quality, soil stability, and environmental conditions that support human life.

Clarification 4: Instruction includes relationships between plant productivity and human population sustainability.

SC.912.P.19.2 Explain how plants provide ecosystem services that benefit human populations.

Benchmark Clarifications:

Clarification 1: Instruction includes provisioning services such as food, fiber, timber, fuel, and other raw materials.

Clarification 2: Instruction includes regulating services such as carbon storage, climate regulation, water regulation, erosion reduction, and air-quality improvement.

Clarification 3: Instruction includes supporting services such as nutrient cycling, soil formation, and habitat development.

Clarification 4: Instruction includes relationships between ecosystem services and environmental stability.

SC.912.P.19.3 Analyze the economic and societal importance of plants.

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Benchmark Clarifications:

Clarification 1: Instruction includes agriculture, forestry, horticulture, and other plant-based economic activities.

Clarification 2: Instruction includes plant resources used in construction, manufacturing, textiles, energy production, and other industries.

Clarification 3: Instruction includes how plant systems influence human communities, economies, and patterns of land use.

Clarification 4: Instruction includes evaluating the importance of sustainable management of plant resources.

SC.912.P.19.4 Explain the role of plants in medicine and human health.

Benchmark Clarifications:

Clarification 1: Instruction includes historical uses of plants in medicine and health practices.

Clarification 2: Instruction includes modern applications of plant-derived compounds in pharmaceuticals and medical treatments.

Clarification 3: Instruction includes examples of how plants contribute to disease treatment, prevention, and human health research.

Clarification 4: Instruction includes how plant biodiversity influences discovery of medicinal compounds.

Clarification 5: Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.P.19.5 Analyze applications of biotechnology used to modify plant characteristics and improve agricultural productivity, disease resistance, and sustainability.

Example: Compare conventionally bred and genetically modified crop varieties.

Example: Investigate plant tissue culture methods used for large-scale propagation.

Example: Evaluate disease-resistant crop technologies.

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Example: Analyze agricultural biotechnology solutions designed to improve food production under changing environmental conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes genetic modification and gene editing.

Clarification 2: Instruction includes marker-assisted selection and modern breeding technologies.

Clarification 3: Instruction includes plant tissue culture and micropropagation.

Clarification 4: Instruction includes development of disease-resistant and stress-tolerant crops.

Clarification 5: Instruction includes biotechnology applications used to improve crop yield, nutritional quality, and agricultural sustainability.

Clarification 6: Instruction includes evaluating scientific evidence used to assess benefits, limitations, and potential impacts of agricultural biotechnology.

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The Science of Animals

How animal cells, body systems, and behaviors support survival, reproduction, and movement, and how animals interact with ecosystems to drive energy flow, matter cycling, and biodiversity.

Grades 9-12

SC.912.A.1 Analyze the structures and functions of animal cells, including the plasma membrane and extracellular matrix (ECM); and explain how cellular components and ECM interactions support, protect, communicate, and regulate the movement of substances within and between cells.

SC.912.A.1.1 Identify the organelles present in animal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the organelles of animal cells: plasma membrane, nucleus, nucleolus, cytoplasm, mitochondria, endoplasmic reticulum, Golgi apparatus (Golgi complex), ribosomes, lysosomes, peroxisomes, centrioles, cytoskeleton, vesicles, and endosomes.

Clarification 2: Instruction includes using models, diagrams, and microscopic images to identify animal-cell organelles and their locations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing microscopic observations and evidence used to identify organelles and explain their functions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.1.2 Illustrate the structure of the plasma membrane of an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes the plasma membrane, which is constructed of two layers of phospholipids made of hydrophilic heads and hydrophobic tails (phospholipid bilayer), embedded proteins, cholesterol, and carbohydrates.

Clarification 2: Instruction includes analyzing quantitative and graphical data related to membrane transport and permeability. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes using membrane models to explain membrane structure and transport processes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating evidence describing relationships among phospholipids, membrane proteins, cholesterol, carbohydrates, and membrane function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes examining historical developments related to membrane structure and the fluid mosaic model and how scientific explanations changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.1.3 Identify the structure of the extracellular matrix (ECM) components in an animal.

Benchmark Clarifications:

Clarification 1: Instruction includes the ECM components: collagen, proteoglycan, fibronectin, laminin, and integrins.

Clarification 2: Instruction includes identifying collagen, proteoglycans, fibronectin, laminin, and integrins in diagrams, models, and microscopic representations.

Clarification 3: Instruction includes using models and representations to explain the organization of extracellular matrix components. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence used to identify extracellular matrix structures and their distributions within tissues. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.1.4 Analyze how the structures of major extracellular matrix (ECM) components in animals relate to their functions in tissue support, cell attachment, and biological processes.

Benchmark Clarifications:

Clarification 1: Instruction includes the ECM components: collagen, proteoglycan, fibronectin, laminin, and integrins.

Clarification 2: Instruction includes that the organization of ECM molecules (fiber alignment, crosslinking, hydration) determines tissue strength, flexibility, and stability.

Clarification 3: Instruction includes that ECM components interact to regulate cell adhesion, communication, migration, and structural integrity.

Clarification 4: Instruction includes that variations in ECM composition allow for specialized tissue functions.

Clarification 5: Instruction includes comparing quantitative measurements of extracellular matrix properties and tissue characteristics. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 6: Instruction includes using structural and systems models to explain relationships between tissue properties, and cellular behavior. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes analyzing observational and experimental evidence used to explain extracellular matrix function in different tissues. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.1.5 Describe the movement of substances in and out of an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes diffusion, osmosis, facilitated diffusion, active transport, and vesicular transport (endocytosis and exocytosis).

Clarification 2: Instruction analyzing graphical and quantitative data related to diffusion rates, osmosis, and membrane transport. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing concentration gradients and transport pathways using diagrams, models, and data. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using observations and investigations to explain movement of substances into and out of animal cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.2 Analyze the structure and functions of the nucleus in an animal cell, including its membranes, internal components, and genetic roles; and explain how the nucleus regulates cell activities, maintains genetic integrity, and supports growth, reproduction, and protein synthesis.

SC.912.A.2.1 Describe the structure of the nucleus of an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes the nucleus, which is surrounded by a double membrane which has nuclear pores that allow exchange of materials between the nucleus and cytoplasm (nuclear envelope).

Clarification 2: Instruction includes that the fluid inside (nucleoplasm) the nucleus contains dissolved ion molecules and enzymes.

Clarification 3: Instruction includes chromatin, which is DNA combined with proteins (histones) contained within the nucleus.

Clarification 4: Instruction includes using models, diagrams, and microscopic images to identify the nuclear envelope, nuclear pores, nucleoplasm, chromatin, and nucleolus. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing microscopic observations and evidence used to identify nuclear structures and explain their functions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.2.2 Identify the location and functions of a nucleolus in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the nucleolus is located in the nucleus of a cell.

Clarification 2: Instruction includes that the nucleolus is the site of ribosome production and the assembly of ribosomal subunits.

Clarification 3: Instruction includes that ribosomal RNA (rRNA) is produced within the nucleolus and combined with proteins to form ribosomal subunits.

Clarification 4: Instruction includes using models and representations to explain nucleolus structure and function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.2.3 Recognize the possibility for multiple nucleoli to be contained within the nucleus of an animal cell.

Benchmark Clarifications:

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Clarification 1: Instruction includes that the number of nucleoli may vary among cell types, physiological conditions, and stages of cellular activity.

Clarification 2: Instruction includes that cells with high rates of protein synthesis often contain multiple nucleoli.

Clarification 3: Instruction includes comparing nucleoli number and appearance among different animal cell types using microscopic observations and evidence. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.2.4 Examine the role of the nucleus in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes storage of deoxyribonucleic acid (DNA), regulating gene expression, directing protein synthesis (mRNA) transcription, and controlling cell cycle progression.

Clarification 2: Instruction includes that the nucleus coordinates cellular activities by regulating which genes are expressed.

Clarification 3: Instruction includes using models and representations to explain how the nucleus regulates cellular functions and protein synthesis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing evidence used to explain relationships among gene expression, protein synthesis, and cellular activities. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes examining historical developments related to the discovery of the nucleus, chromosome organization, and gene regulation and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.2.5 Analyze the role of a nucleolus in protein synthesis in an animal cell.

Benchmark Clarifications:

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Clarification 1: Instruction includes that the nucleolus synthesizes ribosomal RNA (rRNA) and assembles ribosomal subunits.

Clarification 2: Instruction includes that ribosomal subunits leave the nucleus through nuclear pores and participate in protein synthesis within the cytoplasm.

Clarification 3: Instruction includes analyzing the relationship between nucleolus activity and rates of protein production in animal cells.

Clarification 4: Instruction includes using models and representations to explain the role of the nucleolus in ribosome formation and protein synthesis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations and evidence used to explain the role of the nucleolus in protein synthesis. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.2.6 Explain how the nucleus of an animal cell maintains genetic integrity.

Benchmark Clarifications:

Clarification 1: Instruction includes that the nuclear envelope protects DNA from damage.

Clarification 2: Instruction includes that the nucleus contains nuclear pores that regulate the controlled exchange of molecules between the nucleus and cytoplasm.

Clarification 3: Instruction includes that DNA organization, replication, and repair processes contribute to maintaining genetic integrity.

Clarification 4: Instruction includes using models and representations to explain how nuclear structures protect and regulate genetic information. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating evidence describing mechanisms that protect DNA and maintain genetic stability. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.3 Analyze the structure and functions of the cytoplasm, cytoskeleton, and centrioles in an animal cell; and explain how these components support cellular organization, movement, biochemical processes, and division.

SC.912.A.3.1 Explain the unique features of cytoplasm within an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes cytoplasm, which has a basic structure of cytosol, organelles, and the cytoskeleton.

Clarification 2: Instruction includes that cytoplasm is fluid-like and flexible and provides the environment in which many cellular processes and interactions among organelles occur.

Clarification 3: Instruction includes using models and diagrams to identify the major components of cytoplasm and explain their relationships. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing observations and evidence used to explain cytoplasmic organization and cellular function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.3.2 Describe the interaction of the cytoplasm with the organelles of an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that cytoplasm works closely with organelles, such as mitochondria, endoplasmic reticulum, Golgi, lysosomes, and peroxisomes, as part of an integrated cytoplasmic network.

Clarification 2: Instruction includes that cytoplasm provides a medium for communication, transport, and exchange of materials among organelles.

Clarification 3: Instruction includes using systems models to explain interactions among the cytoplasm and organelles as an integrated cellular network. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes analyzing observations and evidence used to explain interactions among organelles within the cytoplasm. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.3.3 Recognize the biochemical reactions that occur within the cytoplasm of an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes metabolic processes such as glycolysis and fermentation.

Clarification 2: Instruction includes that the cytoplasm contains enzymes and substrates needed to support cellular metabolic activities.

Clarification 3: Instruction includes that glycolysis occurs in the cytoplasm and provides products used in cellular respiration.

Clarification 4: Instruction includes analyzing data and evidence used to explain cytoplasmic metabolic processes. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing metabolic pathway models to explain biochemical reactions occurring in the cytoplasm. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.3.4 Determine the role of cytoplasm in the movement of molecules and ions between different parts of an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes the way that the cytoplasm facilitates the transport of materials in a cell.

Clarification 2: Instruction includes the relationship between the transport of materials within a cell, cell signaling molecules, and nutrient distribution.

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Clarification 3: Instruction includes the role of the cytoplasm in the storage of substances like nutrients, enzymes, and waste products until they are needed or expelled.

Clarification 4: Instruction includes analyzing quantitative and graphical data related to intracellular transport and distribution of materials. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing concentration gradients, molecular movement, and intracellular transport using models and representations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using observations and investigations to explain the movement of molecules and ions within animal cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.3.5 Illustrate the structure of centrioles in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that centrioles are found in the centrosome near the nucleus.

Clarification 2: Instruction includes that each centriole is made of nine sets of microtubule triplets arranged in a ring (9x3 structure).

Clarification 3: Instruction includes that centrioles usually occur in pairs inside the centrosome positioned at right angles to each other.

Clarification 4: Instruction includes using models, diagrams, and microscopic representations to identify centriole structure and organization. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing observations and evidence used to identify centrioles and their organization within the centrosome. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.3.6 Describe the structure and functions of the cytoskeleton in an animal cell.

Benchmark Clarifications:

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Clarification 1: Instruction includes microtubules, microfilaments, and intermediate filaments.

Clarification 2: Instruction includes support, shape, intracellular transport, cellular movement, and cell division.

Clarification 3: Instruction includes relationships among the cytoskeleton, organelles, and cellular organization.

Clarification 4: Instruction includes using models, diagrams, and microscopic representations to identify the physical structures and roles of filaments. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.3.7 Describe the structure and functions of centrioles in an animal cell and explain their role in cell organization, movement, and division.

Benchmark Clarifications:

Clarification 1: Instruction includes that centrioles help organize microtubules within the centrosome.

Clarification 2: Instruction includes that centrioles contribute to spindle formation during cell division.

Clarification 3: Instruction includes that centrioles are associated with the formation of basal bodies that support cilia and flagella.

Clarification 4: Instruction includes that centriole organization contributes to cellular structure, intracellular transport, movement, and division.

Clarification 5: Instruction includes using models and representations to explain relationships among centrioles, microtubules, cell organization, and cell division. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes analyzing observations and evidence used to explain centriole function in animal cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.4 Analyze the structure and functions of mitochondria and peroxisomes in an animal cell; and explain how these organelles produce energy, maintain cellular metabolism, and protect the cell from biochemical damage.

SC.912.A.4.1 Describe the structure and functions of mitochondria in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes the outer membrane of mitochondria is smooth and the inner mitochondrial membrane is folded many times (cristae) to increase the surface area.

Clarification 2: Instruction includes the mitochondria which produces energy by converting oxygen and glucose into ATP.

Clarification 3: Instruction includes analyzing quantitative and graphical data relating mitochondrial abundance, surface area, and energy production in animal cells. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes relating mitochondrial structure to ATP production and energy demands of animal cells using structural and functional models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating observations and evidence used to explain mitochondrial structure and function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.4.2 Distinguish the unique characteristics of mitochondria when compared to the nucleus in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that mitochondria contain DNA but not a nucleus, and ribosomes that synthesize proteins.

Clarification 2: Instruction includes that mitochondria contain circular DNA and 70S-type ribosomes and the nucleus contains linear DNA packaged with histones and relies on 80S ribosomes.

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Clarification 3: Instruction includes that mitochondrial DNA is maternal-only and exists in multiple copies per mitochondrion while nuclear DNA is inherited from both parents.

Clarification 4: Instruction includes comparing the structures, genetic material, inheritance patterns, and functions of mitochondria and nuclei using models and representations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing evidence supporting the presence of mitochondrial DNA and its inheritance patterns. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to mitochondria, cellular respiration, and organelle function and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.4.3 Describe the structure and functions of peroxisomes in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes peroxisomes, which are small spherical or oval organelles enclosed by a single lipid bilayer membrane.

Clarification 2: Instruction includes that peroxisome lumens contain oxidative enzymes such as catalase.

Clarification 3: Instruction includes that peroxisomes clean up harmful chemicals and prepare fats for energy use.

Clarification 4: Instruction includes using models and diagrams to identify peroxisome structure and explain relationships between structure and function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating observations and evidence used to identify peroxisomes and explain their functions in animal cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.4.4 Examine the crucial role of peroxisomes for energy metabolism and protecting cells from oxidative damage in an animal.

Benchmark Clarifications:

Clarification 1: Instruction includes that peroxisomes perform beta-oxidation of very long-chain fatty acids turning them into smaller molecules that can be used for energy (energy metabolism).

Clarification 2: Instruction includes that peroxisomes break down toxic compounds such as hydrogen peroxide (H2O2) into water and oxygen using the enzyme catalase.

Clarification 3: Instruction includes that animal cell peroxisomes are important for detoxification in the liver.

Clarification 4: Instruction includes analyzing quantitative and graphical data related to peroxisome activity, fatty acid metabolism, and detoxification processes. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using metabolic and cellular models to explain relationships among fatty acid metabolism, detoxification, and protection from oxidative damage. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating evidence describing the role of peroxisomes in metabolism and cellular protection. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.4.5 Identify the function of peroxisomes based upon the unique metabolic needs of animals.

Benchmark Clarifications:

Clarification 1: Instruction includes the metabolism of amino acids and polyamines.

Clarification 2: Instruction includes the synthesis of plasmalogens which are important for brain and heart function in humans.

Clarification 3: Instruction includes that peroxisomes contribute to lipid metabolism and the production of specialized molecules required for animal tissues.

Clarification 4: Instruction includes that functions of peroxisomes vary among tissues depending on metabolic demands.

Clarification 5: Instruction includes analyzing quantitative data related to lipid metabolism and peroxisome activity in animal cells. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using models and representations to explain relationships between peroxisome function and animal metabolism. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes evaluating evidence used to explain specialized peroxisome functions in animal tissues. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.5 Analyze the structure and functions of lysosomes, vesicles, and endosomes in an animal cell; and explain how these membrane-bound organelles digest materials, transport substances, recycle components, and maintain cellular homeostasis.

SC.912.A.5.1 Describe the structure and functions of lysosomes in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that lysosomes have a single membrane that surrounds a sac filled with hydrolytic enzymes that break down waste materials and recycle useful parts.

Clarification 2: Instruction includes that lysosomes digest damaged organelles, cellular debris, and materials taken into the cell through endocytosis.

Clarification 3: Instruction includes that lysosomes contribute to recycling cellular materials and maintaining cellular homeostasis.

Clarification 4: Instruction includes using models and representations to explain lysosome structure and function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating observations and evidence used to explain lysosome function in animal cells. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.5.2 Examine the role of lysosomal lumen in the function of lysosomes in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that lysosomal lumen is acidic and contains hydrolytic enzymes.

Clarification 2: Instruction includes that the acidic environment of the lysosomal lumen supports the activity of hydrolytic enzymes.

Clarification 3: Instruction includes that compartmentalization within the lysosomal lumen protects the cell from damage caused by digestive enzymes.

Clarification 4: Instruction includes using models and diagrams to explain the relationship between lysosomal lumen conditions and enzyme activity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.5.3 Describe the structure and functions of vesicles in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes vesicles, which are small spherical sacs enclosed by a single phospholipid bilayer membrane that move substances within the cell (intracellular transport),

move substances out of the cell (exocytosis) and bring substances into the cell (endocytosis).

Clarification 2: Instruction includes that vesicles organize a cell by compartmentalizing processes, storing needed molecules, and releasing signaling substances such as hormones or neurotransmitters.

Clarification 3: Instruction includes that vesicles transport materials among organelles including the endoplasmic reticulum, Golgi apparatus, lysosomes, and plasma membrane.

Clarification 4: Instruction includes using models and representations to explain vesicle formation, transport, and fusion with target membranes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes evaluating evidence used to explain vesicle-mediated transport and secretion. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.5.4 Examine the role of vesicle lumen in the function of vesicles in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the vesicle lumen holds the specific molecules a vesicle transports, stores, or releases and keeps them isolated and protected until they reach their destination.

Clarification 2: Instruction includes that the contents of the lumen vary depending on vesicle function and destination.

Clarification 3: Instruction includes that the vesicle lumen provides a protected environment for transported molecules.

Clarification 4: Instruction includes using models to explain relationships among vesicle structure, lumen contents, and cellular function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.5.5 Classify different types of vesicles based upon their functions in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes transport, secretory, and endocytic vesicles.

Clarification 2: Instruction includes comparing transport, secretory, and endocytic vesicles based on origin, contents, and destination.

Clarification 3: Instruction includes using models and diagrams to classify vesicles according to their cellular functions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes evaluating evidence used to identify different vesicle types and functions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.5.6 Describe the structure and functions of endosomes.

Benchmark Clarifications:

Clarification 1: Instruction includes endosomes, which are membrane-bound vesicular compartments enclosed by a single phospholipid bilayer, with a lumen that contains endocytosed materials and enzymes for sorting and processing.

Clarification 2: Instruction includes that endosomes sort and direct internalized molecules to support nutrient uptake, receptor recycling, cell signaling, and homeostasis.

Clarification 3: Instruction includes that endosomes receive vesicles formed during endocytosis and direct materials to lysosomes, recycling pathways, or other cellular destinations.

Clarification 4: Instruction includes using models and diagrams to explain sorting and trafficking functions of endosomes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating observations and evidence used to explain endosome structure and function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.5.7 Classify different types of endosomes based upon their functions in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes early, late, and recycling endosomes.

Clarification 2: Instruction includes that early endosomes receive and sort materials entering the cell through endocytosis.

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Clarification 3: Instruction includes that late endosomes transport materials toward lysosomes for digestion and processing.

Clarification 4: Instruction includes that recycling endosomes return selected molecules and receptors to the plasma membrane.

Clarification 5: Instruction includes analyzing quantitative and graphical data related to intracellular transport and trafficking. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using models and representations to compare functions of early, late, and recycling endosomes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes evaluating evidence used to classify endosomes and explain intracellular trafficking pathways. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.6 Analyze the structure and functions of ribosomes, the endoplasmic reticulum, and the Golgi apparatus (Golgi Complex) in an animal cell; and explain how these organelles synthesize, modify, and transport proteins and lipids necessary for cellular communication, secretion, and homeostasis.

SC.912.A.6.1 Describe the structure and functions of ribosomes in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that ribosomes are made of large and small subunits that join together during protein synthesis.

Clarification 2: Instruction includes that ribosomes read mRNA instructions and assemble amino acids into proteins that serve as enzymes, structural components, and signaling molecules.

SC.912.A.6.2 Distinguish the differences between free and attached ribosomes within an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that free ribosomes float in the cytoplasm and produce proteins used inside the cell, including enzymes for metabolism and proteins for organelles and cytoplasmic function.

Clarification 2: Instruction includes that attached ribosomes on the rough endoplasmic reticulum produce proteins that are secreted, inserted into the cell membrane, or sent to organelles such as for receptors or digestive enzymes.

SC.912.A.6.3 Describe the structure and functions of endoplasmic reticulum in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the endoplasmic reticulum is an extensive network of membrane-bound sacs and tubules continuous with the nuclear envelope, with a lumen (cisternal space) enclosed by a single phospholipid bilayer.

Clarification 2: Instruction includes that the endoplasmic reticulum consists of two regions: rough endoplasmic reticulum (with ribosomes) and smooth endoplasmic reticulum (without ribosomes).

SC.912.A.6.4 Describe the function of the rough endoplasmic reticulum within an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the rough endoplasmic reticulum synthesizes and begins processing proteins through ribosomes attached to its surface.

Clarification 2: Instruction includes that the rough endoplasmic reticulum works with ribosomes, vesicles, and the Golgi to fold, modify, package, and transport proteins to their destinations.

SC.912.A.6.5 Describe the function of the smooth endoplasmic reticulum within an animal cell.

Benchmark Clarifications:

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Clarification 1: Instruction includes that the smooth endoplasmic reticulum synthesizes lipids such as fats and steroids, detoxifies harmful chemicals, and stores calcium ions for processes such as muscle contraction.

SC.912.A.6.6 Describe the structure and functions of the Golgi apparatus (Golgi complex) in an animal cell.

Benchmark Clarifications:

Clarification 1: Instruction includes that the Golgi consists of a series of flattened membrane bound sacs (cisternae), each with a lumen enclosed by a single lipid bilayer and is polarized with a cis face for receiving materials and a trans face for shipping them.

Clarification 2: Instruction includes that the Golgi apparatus processes, modifies, and sorts proteins and lipids received from the endoplasmic reticulum, and packages them into vesicles that deliver their contents to the cell membrane for secretion, to lysosomes for digestion, or to other cellular destinations.

SC.912.A.6.7 Examine the role of the Golgi apparatus (Golgi complex) in cell signaling within an animal.

Benchmark Clarifications:

Clarification 1: Instruction includes that the Golgi modifies signaling molecules and receptors received from the endoplasmic reticulum, packages them into vesicles for secretion, and delivers receptor proteins to the cell membrane to enable cell to cell signaling.

SC.912.A.7 Analyze the major animal phyla by examining their structural and functional characteristics, including body symmetry, tissue layers, body cavities, segmentation, appendages, locomotion, respiration, reproduction, and ecological roles; and explain their classification within Kingdom Animalia.

SC.912.A.7.1 Describe the basic organization, symmetry, and habitat of Porifera.

Benchmark Clarifications:

Clarification 1: Instruction includes that Porifera are simple, multicellular, sessile animals that live primarily in aquatic environments.

Clarification 2: Instruction includes that most Porifera are asymmetrical, but some exhibit radial symmetry.

Clarification 3: Instruction includes that Porifera bodies contain many pores for water flow, have a central cavity (spongocoel), an osculum where water exits, and a skeleton composed of calcareous or siliceous spicules.

SC.912.A.7.2 Explain feeding and digestion in Porifera.

Benchmark Clarifications:

Clarification 1: Instruction includes that Porifera are filter feeders whose digestion occurs inside cells (intracellularly).

Clarification 2: Instruction includes that Porifera feed by drawing water through pores, where collar cells (choanocytes) trap food particles.

SC.912.A.7.3 Describe reproduction in Porifera.

Benchmark Clarifications:

Clarification 1: Instruction includes that Porifera reproduce both sexually and asexually.

Clarification 2: Instruction includes that asexual reproduction occurs through budding, fragmentation, and gemmules.

Clarification 3: Instruction includes that sexual reproduction involves production of both sperm and egg cells and promotes genetic diversity.

SC.912.A.7.4 Explain respiration in Porifera.

Benchmark Clarifications:

Clarification 1: Instruction includes that Porifera perform respiration by moving water through their bodies, enabling gas exchange by diffusion across cell surfaces.

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SC.912.A.7.5 Describe organization, symmetry, and tissues in Cnidaria.

Benchmark Clarifications:

Clarification 1: Instruction includes that Cnidaria are simple, multicellular animals with true tissues but no organs and live mostly in aquatic environments.

Clarification 2: Instruction includes that Cnidaria are diploblastic with two germ layers: ectoderm and endoderm.

Clarification 3: Instruction includes that Cnidaria exhibit radial symmetry.

SC.912.A.7.6 Explain feeding, defense, and digestion in Cnidaria.

Benchmark Clarifications:

Clarification 1: Instruction includes that Cnidaria have a single opening that serves as both mouth and anus, leading to a gastrovascular cavity for digestion.

Clarification 2: Instruction includes that Cnidaria possess specialized stinging cells (cnidocytes) containing nematocysts that inject toxins to capture prey and for defense.

SC.912.A.7.7 Describe body forms, nervous organization, and responses to stimuli in Cnidaria.

Benchmark Clarifications:

Clarification 1: Instruction includes that most Cnidaria have one of two body forms: sessile polyp or free-swimming medusa.

Clarification 2: Instruction includes that Cnidaria lack a central nervous system and respond to stimuli using a simple nerve net rather than a brain.

SC.912.A.7.8 Describe reproduction and life cycles in Cnidaria.

Benchmark Clarifications:

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Clarification 1: Instruction includes that Cnidaria reproduce both sexually and asexually.

Clarification 2: Instruction includes that asexual reproduction occurs by budding in polyps, and sexual reproduction involves gamete production in medusae.

SC.912.A.7.9 Classify major Cnidarian groups and explain respiration.

Benchmark Clarifications:

Clarification 1: Instruction includes four main Cnidarian groups: Anthozoa (sea anemones, corals, sea pens), Scyphozoan (jellyfish), Cubozoan (box jellyfish), and Hydrozoa (Hydra, Portuguese man o' war).

Clarification 2: Instruction includes that Cnidaria perform respiration by diffusion across body surfaces as water flows over tissues.

Clarification 3: Instruction includes using classification diagrams, organism models, and anatomical representations to distinguish major Cnidarian groups and explain shared characteristics. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing anatomical observations and classification evidence used to distinguish major Cnidarian groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.7.10 Describe the body plan and organization of Platyhelminthes.

Benchmark Clarifications:

Clarification 1: Instruction includes that Platyhelminthes are bilaterally symmetrical, triploblastic, and acoelomate, which results in a flattened body.

Clarification 2: Instruction includes that Platyhelminthes exhibit cephalization, with a concentration of sensory structures at the head.

SC.912.A.7.11 Explain organ systems and digestion in Platyhelminthes.

Benchmark Clarifications:

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Clarification 1: Instruction includes that Platyhelminthes lack circulatory and respiratory systems and rely on diffusion for gas exchange.

Clarification 2: Instruction includes that Platyhelminthes may have an incomplete digestive system with one opening serving as mouth and anus, or in parasitic forms, lack a digestive system and absorb nutrients from the host.

Clarification 3: Instruction includes that Platyhelminthes have a simple nervous system with longitudinal nerve cords and cerebral ganglia.

SC.912.A.7.12 Describe reproduction in Platyhelminthes.

Benchmark Clarifications:

Clarification 1: Instruction includes that Platyhelminthes reproduce both asexually and sexually.

Clarification 2: Instruction includes that asexual reproduction occurs through regeneration, where body fragments can form new individuals.

Clarification 3: Instruction includes that sexual reproduction involves the production of both sperm and eggs; cross-fertilization is common, and some can self-fertilize.

SC.912.A.7.13 Describe the body plan and coverings of Nematoda.

Benchmark Clarifications:

Clarification 1: Instruction includes that Nematoda are bilaterally symmetrical, triploblastic, and pseudocoelomate.

Clarification 2: Instruction includes that Nematoda have elongated, cylindrical, unsegmented bodies covered by a tough cuticle that is periodically shed (molting).

SC.912.A.7.14 Explain systems and basic functions in Nematoda.

Benchmark Clarifications:

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Clarification 1: Instruction includes that Nematoda have a complete digestive system with a separate mouth and anus.

Clarification 2: Instruction includes that Nematoda have a simple nervous system with a nerve ring around the pharynx and longitudinal nerve cords.

Clarification 3: Instruction includes that Nematoda lack circulatory and respiratory systems and rely on diffusion for gas exchange.

SC.912.A.7.15 Describe reproduction and ecological roles in Nematoda.

Benchmark Clarifications:

Clarification 1: Instruction includes that Nematoda mostly reproduce sexually with separate sexes (dioecious) and internal fertilization.

Clarification 2: Instruction includes that some Nematoda are parasitic and cause diseases in plants and animals, while others are free-living and play vital roles in soil ecosystems.

SC.912.A.7.16 Describe the segmented body plans and locomotion of Annelida.

Benchmark Clarifications:

Clarification 1: Instruction includes that Annelida are bilaterally symmetrical, triploblastic, and coelomate.

Clarification 2: Instruction includes that Annelida bodies are divided into internal and external segments and are covered by a moist cuticle.

Clarification 3: Instruction includes that many Annelids have bristle-like setae on segments for locomotion.

SC.912.A.7.17 Explain digestion and respiration in Annelida.

Benchmark Clarifications:

Clarification 1: Instruction includes that Annelida have a complete digestive system with a mouth and a separate anus.

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Clarification 2: Instruction includes that Annelida perform respiration through their body surface (cutaneous respiration) and, in some aquatic groups, by gills.

SC.912.A.7.18 Describe reproduction and fertilization strategies in Annelida.

Benchmark Clarifications:

Clarification 1: Instruction includes that Annelida reproduce both asexually and sexually.

Clarification 2: Instruction includes that some Annelida reproduce asexually through fragmentation or budding.

Clarification 3: Instruction includes that many Annelida reproduce sexually by producing sperm and eggs, with cross-fertilization common and some capable of self-fertilization.

Clarification 4: Instruction includes that aquatic Annelids commonly release gametes for external fertilization, while terrestrial Annelids exchange sperm during mating and later fertilize eggs internally.

SC.912.A.7.19 Describe the body plan and classification of Mollusca.

Benchmark Clarifications:

Clarification 1: Instruction includes that Mollusca are bilaterally symmetrical, triploblastic, and coelomate.

Clarification 2: Instruction includes that Mollusca are soft-bodied animals typically composed of a foot, visceral mass, and mantle, and many have a hard shell.

Clarification 3: Instruction includes four class groupings: Gastropoda, Bivalvia, Cephalopoda, and others such as Polyplacophora, “tusk shells” (Scaphopoda), and Monoplacophora.

Clarification 4: Instruction includes using classification diagrams, anatomical models, and comparative representations to distinguish major groups within Mollusca. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes analyzing anatomical observations and classification evidence used to identify major Molluscan groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.7.20 Describe locomotion, nervous systems, and feeding structures in Mollusca.

Benchmark Clarifications:

Clarification 1: Instruction includes that the muscular foot is used for locomotion.

Clarification 2: Instruction includes that Molluscan nervous systems range from simple such as scallops to highly developed.

Clarification 3: Instruction includes that some Mollusca have a tongue-like structure with teeth (radula) for scraping food.

SC.912.A.7.21 Explain feeding strategies and respiration in Mollusca.

Benchmark Clarifications:

Clarification 1: Instruction includes that most bivalves are filter feeders, while many cephalopods are predators or scavengers.

Clarification 2: Instruction includes that aquatic Mollusca breathe using gills (ctenidia) in a mantle cavity through which water flows for gas exchange.

Clarification 3: Instruction includes that terrestrial Mollusca breathe using a modified mantle cavity that functions like a lung.

SC.912.A.7.22 Describe reproduction and fertilization strategies in Mollusca.

Benchmark Clarifications:

Clarification 1: Instruction includes that Mollusca mostly reproduce sexually, with some having larval stages.

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Clarification 2: Instruction includes that asexual reproduction is rare but occurs via parthenogenesis in some Bivalvia and Gastropoda.

Clarification 3: Instruction includes that fertilization may be internal or external; aquatic forms often release eggs and sperm into the water, while terrestrial forms typically exchange sperm and fertilize internally.

SC.912.A.7.23 Describe the body plan and protective structures of Arthropoda.

Benchmark Clarifications:

Clarification 1: Instruction includes that Arthropods are bilaterally symmetrical, triploblastic, and coelomate.

Clarification 2: Instruction includes that Arthropods have an exoskeleton made of chitin that protects the body, reduces water loss, and is shed during growth (molting).

Clarification 3: Instruction includes that Arthropods have segmented bodies divided into regions and jointed appendages for specialized movement and functions.

SC.912.A.7.24 Explain sensory and respiratory systems in Arthropoda.

Benchmark Clarifications:

Clarification 1: Instruction includes that Arthropods have well-developed nervous systems; many have compound eyes and antennae that detect vibrations, chemicals, and touch.

Clarification 2: Instruction includes that respiratory structures vary: insects use tracheal tubes, arachnids use book lungs or tracheae, and crustaceans use gills.

SC.912.A.7.25 Describe reproduction, development, and life cycles in Arthropoda.

Benchmark Clarifications:

Clarification 1: Instruction includes that most Arthropods reproduce sexually, with fertilization either internal or external depending on the group.

Clarification 2: Instruction includes that many Arthropods undergo complete metamorphosis or incomplete metamorphosis.

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SC.912.A.7.26 Explain ecological roles and adaptive success in Arthropoda.

Benchmark Clarifications:

Clarification 1: Instruction includes that Arthropods serve as pollinators, decomposers, and foundational members of food webs.

Clarification 2: Instruction includes that Arthropods' success reflects rapid reproduction, protective exoskeletons, quick adaptation, and occupation of nearly every habitat.

Clarification 3: Instruction includes analyzing biodiversity, abundance, and ecological distribution data to explain the adaptive success of Arthropoda. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using ecological and systems models to explain relationships among Arthropod adaptations, survival, reproduction, and ecological success. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing ecological evidence used to explain the roles of Arthropods in ecosystems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.7.27 Describe the body plan and habitat of Echinodermata.

Benchmark Clarifications:

Clarification 1: Instruction includes that Echinoderms have five-part radial symmetry, are triploblastic, and coelomate.

Clarification 2: Instruction includes that Echinoderms live exclusively in marine environments.

SC.912.A.7.28 Explain locomotion, water vascular system, and respiration in Echinodermata.

Benchmark Clarifications:

Clarification 1: Instruction includes that Echinoderms move using tube feet operated by hydraulic pressure.

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Clarification 2: Instruction includes that Echinoderms lack a true circulatory system and respirate through tube feet and skin gills, using the water vascular system to distribute nutrients and gases.

SC.912.A.7.29 Describe feeding strategies in Echinodermata.

Benchmark Clarifications:

Clarification 1: Instruction includes that some Echinoderms are predators, such as sea urchins scrape algae using Aristotle's lantern and sea cucumbers filter feed or consume detritus.

SC.912.A.7.30 Describe reproduction, regeneration, and ecological roles in Echinodermata.

Benchmark Clarifications:

Clarification 1: Instruction includes that Echinoderms reproduce both asexually and sexually.

Clarification 2: Instruction includes that some Echinoderms reproduce asexually by fragmentation, and many reproduce sexually by releasing eggs and sperm into the water for external fertilization.

Clarification 3: Instruction includes that Echinoderms can regenerate lost body parts and play key roles in marine ecosystems, including controlling algae and shellfish populations.

SC.912.A.7.31 Identify the defining characteristics of Chordata.

Benchmark Clarifications:

Clarification 1: Instruction includes four defining features of chordates: notochord, dorsal hollow nerve cord, pharyngeal slits, and post-anal tail.

Clarification 2: Instruction includes that the notochord is a flexible rod that provides support and becomes the backbone in vertebrates.

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Clarification 3: Instruction includes that the dorsal hollow nerve cord is a tube along the back of chordate embryos that develops into the central nervous system and supports advanced movement and complex behaviors.

Clarification 4: Instruction includes that pharyngeal slits are used for filter feeding in some groups and develop into throat and ear structures in humans.

Clarification 5: Instruction includes that the post-anal tail extends beyond the anus and may be reduced or lost in adults.

SC.912.A.7.32 Classify chordates into invertebrate and vertebrate groups.

Benchmark Clarifications:

Clarification 1: Instruction includes that chordates include invertebrates and vertebrates.

Clarification 2: Instruction includes that vertebrate chordates include fish, amphibians, reptiles, birds, and mammals.

Clarification 3: Instruction includes using classification diagrams, cladograms, and comparative anatomical models to distinguish invertebrate and vertebrate chordates. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing anatomical observations and classification evidence used to group chordates. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.7.33 Describe core vertebrate characteristics and body organization.

Benchmark Clarifications:

Clarification 1: Instruction includes that vertebrates have an internal skeleton (endoskeleton) and advanced organ systems.

Clarification 2: Instruction includes that vertebrates are bilaterally symmetrical, triploblastic, and coelomate.

Clarification 3: Instruction includes that vertebrates possess complete digestive systems.

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SC.912.A.7.34 Recognize notable sensory and adaptive features within vertebrates.

Benchmark Clarifications:

Clarification 1: Instruction includes that the dorsal hollow nerve cord enables complex processing, learning, and coordination of body functions in vertebrates.

Clarification 2: Instruction includes that some vertebrates possess specialized sensory adaptations such as Jacobson's organ (vomeronasal organ).

SC.912.A.7.35 Describe diversity and exceptional cases among vertebrates.

Benchmark Clarifications:

Clarification 1: Instruction includes examples of unique vertebrate adaptations and life histories.

Clarification 2: Instruction includes comparing vertebrate groups using structural, physiological, and reproductive characteristics.

Clarification 3: Instruction includes analyzing biodiversity and classification data to compare vertebrate groups. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using classification diagrams, comparative anatomical models, and phylogenetic representations to compare vertebrate groups. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing classification evidence used to group vertebrates. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to animal classification, comparative anatomy, evolutionary relationships, and vertebrate diversity and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.A.8 Analyze the structural, functional, and ecological characteristics of fish; and explain their adaptations, biological systems, sensory capabilities, classification, life processes, and roles within aquatic ecosystems.

SC.912.A.8.1 Examine fish as a type of vertebrate.

Benchmark Clarifications:

Clarification 1: Instruction includes that fish are vertebrate, ectothermic animals.

Clarification 2: Instruction includes the major groups of fish: jawless (Agnatha), bony (Osteichthyes), and cartilaginous (Chondrichthyes).

Clarification 3: Instruction includes the basic anatomy of a fish: fins, scales, lateral line, gills, heart, and swim bladder.

Clarification 4: Instruction includes comparing fish to other vertebrates.

SC.912.A.8.2 Analyze how fish maintain homeostasis in aquatic environments.

Benchmark Clarifications:

Clarification 1: Instruction includes freshwater and marine waters.

Clarification 2: Instruction includes that fish regulate water (osmoregulation) as water moves in or out of their bodies by osmosis depending on where they live.

Clarification 3: Instruction includes relationships among salinity, dissolved oxygen, temperature, pH, and physiological processes in marine fishes.

Clarification 4: Instruction includes analyzing salinity, water balance, and environmental data to explain osmoregulatory responses in freshwater and marine fish. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using models to predict osmoregulatory responses in freshwater and marine environments. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.8.3 Examine the adaptations of fish that enable them to survive in marine waters.

Benchmark Clarifications:

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Clarification 1: Instruction includes the physical and behavioral adaptations that help fish survive life in the ocean.

SC.912.A.8.4 Examine the role of fish in ocean zones.

Benchmark Clarifications:

Clarification 1: Instruction includes horizontal zones: intertidal, neritic, and oceanic.

Clarification 2: Instruction includes vertical zones: sunlit (epipelagic) zone, twilight (mesopelagic) zone, midnight (bathypelagic) zone, the abyss (abyssopelagic), and trenches (hadalpelagic).

Clarification 3: Instruction includes relationships among wave energy, water movement, habitat structure, and fish distribution across marine zones.

SC.912.A.8.5 Determine the role of fish in biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes the cycling of carbon, nitrogen, and phosphorus.

Clarification 2: Instruction includes that fish assist the regulation of ocean chemistry and nutrient availability.

SC.912.A.8.6 Analyze the relationship between fish behaviors and ocean patterns.

Benchmark Clarifications:

Clarification 1: Instruction includes large-scale and vertical migration.

Clarification 2: Instruction includes how fish navigate currents, use magnetic fields, and follow temperature gradients.

Clarification 3: Instruction includes that migration connects different ocean regions and affects ecosystems globally.

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Clarification 4: interpreting migration maps, population data, and environmental datasets to explain relationships among fish behavior, ocean conditions, and ecosystem connectivity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using migration maps, ocean-current models, and geographic representations to explain fish movement patterns and environmental influences. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.8.7 Analyze the role of fish in transferring energy between lower-level producers and higher-level predators.

Benchmark Clarifications:

Clarification 1: Instruction includes that fish occupy multiple trophic levels and transfer energy from producers and lower-level consumers to higher-level predators.

Clarification 2: Instruction includes that fish contribute to the movement of matter and energy within aquatic food webs.

Clarification 3: Instruction includes analyzing food-web, biomass, and population data to explain energy transfer through aquatic ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using food-web and ecosystem models to explain the role of fish in energy transfer within aquatic ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.8.8 Examine the anthropogenic impacts on fish.

Benchmark Clarifications:

Clarification 1: Instruction includes positive impacts such as establishing protected areas, developing sustainable fishing practices, restoring habitats, controlling pollution, and building artificial reefs.

Clarification 2: Instruction includes negative impacts such as species decline due to overfishing, habitat disturbance due to pollution, water temperature changes, and coral bleaching.

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Clarification 3: Instruction includes analyzing population, habitat, and environmental data used to evaluate human impacts on fish populations and ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes using ecological and systems models to explain positive and negative human impacts on fish populations and aquatic ecosystems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating evidence used to assess human impacts on fish populations and ecosystems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.8.9 Examine the impacts of natural disasters on fish.

Benchmark Clarifications:

Clarification 1: Instruction includes the impacts of hurricanes and red tide (harmful algal blooms).

SC.912.A.8.10 Examine fish in freshwater systems.

Benchmark Clarifications:

Clarification 1: Instruction includes lotic and lentic waters.

SC.912.A.8.11 Analyze the impact of invasive species on fish.

Benchmark Clarifications:

Clarification 1: Instruction includes the impact of both plant and animal invasive species.

Clarification 2: Instruction includes that invasive species may alter food webs, compete for resources, modify habitats, and affect fish populations.

Clarification 3: Instruction includes analyzing population and ecosystem data to evaluate impacts of invasive species. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes using ecosystem and food-web models to predict the effects of invasive species on aquatic communities. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes analyzing ecological evidence used to evaluate the effects of invasive species on fish populations and aquatic ecosystems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.8.12 Explore the features of a fish that determine how they are classified in Kingdom Animalia.

Benchmark Clarifications:

Clarification 1: Instruction includes characteristics used to classify fish including vertebral column, body symmetry, tissue organization, body coverings, skeletal structure, reproductive traits, and developmental characteristics.

Clarification 2: Instruction includes distinguishing jawless, cartilaginous, and bony fishes using anatomical characteristics.

Clarification 3: Instruction includes using classification diagrams, cladograms, and comparative anatomical models to classify fish within Kingdom Animalia. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing anatomical observations and classification evidence used to distinguish major fish groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.8.13 Analyze how fish have developed behavioral, structural, and physiological adaptations that enable them to survive in various aquatic environments.

Benchmark Clarifications:

Clarification 1: Instruction includes behavioral adaptations such as schooling for protection and efficiency; migration for reproduction or feeding; territorial feeding, and reproductive behaviors; and predator avoidance.

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Clarification 2: Instruction includes structural adaptations such as streamlined body shape for movement; fins for propulsion, steering, and balance; gills for gas exchange; scales and mucus for protection and reduced friction; lateral lined systems for detecting vibrations; and swim bladders that assist with buoyancy.

Clarification 3: Instruction includes physiological adaptations regulation of buoyancy, oxygen extraction through gill structures, osmoregulation to maintain internal water and salt balance, temperature tolerance, and metabolic adaptations.

Clarification 4: Instruction includes using ecological and biological models to explain relationships among environmental conditions and behavioral, structural, and physiological adaptations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes evaluating evidence used to explain adaptations that support survival in aquatic environments. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.9 Analyze the structural, functional, and ecological characteristics of amphibians; and explain their adaptations, body systems, sensory capabilities, classification, life processes, metamorphosis, and roles within terrestrial and aquatic environments.

SC.912.A.9.1 Examine amphibians as a type of vertebrate.

Benchmark Clarifications:

Clarification 1: Instruction includes that amphibians are vertebrate, ectothermic animals known for living in both aquatic and terrestrial environments.

Clarification 2: Instruction includes the three types of amphibians: frogs and toads (Anura), salamanders and newts (Caudata), and caecilians (Gymnophiona).

Clarification 3: Instruction includes the anatomy of an amphibian that enables it to grow, reproduce, and survive in aquatic and terrestrial environments.

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SC.912.A.9.2 Analyze how amphibians maintain homeostasis through behavior, temperature regulation, and water balance.

SC.912.A.9.3 Examine the adaptations of amphibians that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes physical and behavioral adaptations that help amphibians grow, reproduce, and survive.

SC.912.A.9.4 Examine the role of amphibians as a bioindicator species.

Benchmark Clarifications:

Clarification 1: Instruction includes amphibians as indicators of ecosystem health because of their sensitivity to environmental conditions.

Clarification 2: Instruction includes analyzing amphibian population, water-quality, and habitat data to evaluate ecosystem health. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes evaluating evidence linking amphibian population changes to ecosystem conditions. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.9.5 Determine the role of amphibians in biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes the cycling of nitrogen, carbon, phosphorus, and water.

Clarification 2: Instruction includes how the dual life stages of amphibians assist in the movement of energy and matter between aquatic and terrestrial environments.

SC.912.A.9.6 Analyze the impact of migration and movement on amphibians.

Benchmark Clarifications:

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Clarification 1: Instruction includes the risks and benefits of amphibian migration and movement.

Clarification 2: Instruction includes how amphibians use chemical signals, moisture gradients, temperature changes, magnetic fields, and memory to navigate.

SC.912.A.9.7 Analyze the role of amphibians in transferring energy between lower-level producers and higher-level predators.

Benchmark Clarifications:

Clarification 1: Instruction includes that amphibians function as both predators and prey and transfer energy between aquatic and terrestrial food webs.

Clarification 2: Instruction includes using food-web and ecosystem models to explain the role of amphibians in energy transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.9.8 Examine the anthropogenic impacts on amphibians.

Benchmark Clarifications:

Clarification 1: Instruction includes positive impacts such as establishing protected areas, restoring habitats, controlling pollution, and constructing road tunnels and crossing structures to reduce amphibian road mortality.

Clarification 2: Instruction includes negative impacts such as disease spread, habitat loss and fragmentation, pollution and chemical exposure, and introduction of invasive species.

SC.912.A.9.9 Examine the impacts of natural disasters on amphibians.

Benchmark Clarifications:

Clarification 1: Instruction includes the impacts of drought, hurricanes, wildfires, freezing temperatures, and flooding.

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SC.912.A.9.10 Analyze the impact of invasive species on amphibians.

Benchmark Clarifications:

Clarification 1: Instruction includes the impact of both plant and animal invasive species.

Clarification 2: Instruction includes using food-web and ecosystem models to predict effects of invasive species on amphibian populations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing ecological evidence used to evaluate invasive species impacts on amphibian populations and habitats. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.9.11 Explore the features of amphibians that determine how they are classified in Kingdom Animalia.

Benchmark Clarifications:

Clarification 1: Instruction includes characteristics used to classify amphibians including vertebral column, skin structure, reproductive traits, developmental patterns, and body organization.

Clarification 2: Instruction includes using classification diagrams, cladograms, and comparative anatomical models to classify amphibians within Kingdom Animalia. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing anatomical observations and classification evidence used to distinguish amphibian groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.9.12 Analyze how amphibians have developed behavioral, structural, and physiological adaptations that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes behavioral adaptations such as breeding calls, camouflage, and chemical defenses.

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Clarification 2: Instruction includes structural adaptations such as moist skin, gills as larvae, lungs as adults, strong limbs, sensory structures, reproductive traits, and body systems that adjust during metamorphosis.

Clarification 3: Instruction includes physiological adaptations such as flexible, dual purpose body systems that assist them with growth, survival, and reproduction across changing environments.

SC.912.A.9.13 Examine the impact of Chytrid fungi (Batrachochytrium dendrobatidis and Batrachochytrium salamandrivorans) on amphibian populations.

Benchmark Clarifications:

Clarification 1: Instruction includes interpreting disease prevalence and population data related to chytrid fungi. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.10 Analyze the structural, functional, and ecological characteristics of reptiles; and explain their adaptations, body systems, sensory capabilities, classification, life processes, and roles within terrestrial, freshwater, and marine ecosystems.

SC.912.A.10.1 Examine reptiles as a type of vertebrate.

Benchmark Clarifications:

Clarification 1: Instruction includes that reptiles are vertebrate, ectothermic animals.

Clarification 2: Instruction includes the main types of reptiles: turtles, tortoises, and terrapins (Testudines); lizards and snakes (Squamata); crocodiles, alligators, and caimans (Crocodilia); and tuataras (Rhynchocephalian).

Clarification 3: Instruction includes the basic anatomy of a reptile: scaly skin, lung-based respiration, heart, kidneys, cloaca, internal fertilization, bony skeleton, and highly specialized sensory organs.

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SC.912.A.10.2 Analyze how reptiles maintain homeostasis through behavior, temperature regulation, and water balance.

Clarification 1: Instruction includes analyzing and comparing the metabolic energy demands of ectothermy and endothermy by evaluating how reptiles survive in resource-scarce habitats.

Clarification 2: Instruction includes graphing the relationship between internal body temperature and ambient environmental temperature over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes modeling heat transfer mechanisms such as radiative absorption during basking, conductive exchange with soil, and convective cooling in shade or burrows. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.10.3 Examine the adaptations of reptiles that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes physical and behavioral adaptations that help reptiles grow, reproduce, and survive.

SC.912.A.10.4 Analyze the unique features of reptiles.

Benchmark Clarifications:

Clarification 1: Instruction includes that reptiles have dry, keratinized scales; lay leathery, amniotic eggs; breathe only with lungs; regulate temperature through behavior; and conserve water using uric acid.

SC.912.A.10.5 Determine the roles of reptiles in biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes how reptilian metabolic activities, waste deposition, and shell or bone formation contribute to carbon, nitrogen, phosphorus, and calcium cycling in aquatic and terrestrial ecosystems.

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SC.912.A.10.6 Analyze the impact of migration and movement on reptiles.

Benchmark Clarifications:

Clarification 1: Instruction includes analyzing migration and movement data to examine impacts on survival and reproduction. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 2: Instruction includes using movement maps and ecological models to explain reptile dispersal and habitat use. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.10.7 Analyze the role of reptiles in transferring energy.

Benchmark Clarifications:

Clarification 1: Instruction includes trophic roles of reptiles as predators, herbivores, and omnivores in food webs.

Clarification 2: Instruction includes that reptiles transfer energy and matter among trophic levels and contribute to ecosystem stability.

Clarification 3: Instruction includes using food-web models to explain the role of reptiles in energy transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.10.8 Examine the anthropogenic impacts on reptiles.

Benchmark Clarifications:

Clarification 1: Instruction includes positive impacts such as conservation programs and laws, habitat restoration, and public education.

Clarification 2: Instruction includes negative impacts such as habitat loss and fragmentation, pollution, introduction of invasive species, illegal trade, road mortality, and disease spread.

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SC.912.A.10.9 Examine the impacts of natural disasters on reptiles.

Benchmark Clarifications:

Clarification 1: Instruction includes natural disasters such as hurricanes, freezing temperatures, flooding, wildfires, and drought.

SC.912.A.10.10 Analyze the impact of invasive species on reptiles.

Benchmark Clarifications:

Clarification 1: Instruction includes the impact of both plant and animal invasive species through predation, competition, and habitat alteration.

Clarification 2: Evaluate population datasets to analyze how invasive plant and animal species disrupt native reptile populations. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 3: Instruction includes analyzing ecological evidence used to evaluate invasive species impacts on reptile populations and ecosystems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.10.11 Explore the features of reptiles that determine how they are classified in Kingdom Animalia.

Benchmark Clarifications:

Clarification 1: Instruction includes characteristics used to classify reptiles including vertebral column, amniotic egg development, keratinized scales, internal fertilization, body organization, and skeletal features.

Clarification 2: Instruction includes distinguishing major reptile groups using anatomical, physiological, reproductive, and developmental characteristics.

Clarification 3: Instruction includes using classification diagrams, cladograms, and comparative anatomical models to classify reptiles within Kingdom Animalia. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 4: Instruction includes analyzing anatomical observations and classification evidence used to distinguish reptile groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.10.12 Analyze how reptiles have developed behavioral, structural, and physiological adaptations that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes behavioral adaptations such as regulating body temperature by basking, burrowing, or nesting; specialized hunting skills; and habitat shifting between aquatic and terrestrial environments.

Clarification 2: Instruction includes structural adaptations such as dry, waterproof skin and scales; large, efficient lungs; body shapes for specific environments; and protective body structures.

Clarification 3: Instruction includes physiological adaptations that reduce water loss, remove excess salts, conserve oxygen for long dives, and manage temperature stress.

SC.912.A.11 Analyze the structural, functional, and ecological characteristics of birds; and explain their adaptations, body systems, sensory capabilities, classification, life processes, and roles within terrestrial, freshwater, and marine ecosystems.

SC.912.A.11.1 Examine birds as a type of vertebrate.

Benchmark Clarifications:

Clarification 1: Instruction includes that birds are vertebrate, endothermic animals.

Clarification 2: Instruction includes the main types of birds: perching birds, birds of prey, waterfowl, ground birds, owls, parrots, woodpeckers, penguins, seabirds, and flightless running birds.

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Clarification 3: Instruction includes the basic anatomy of a bird: feathers, lightweight skeleton, highly efficient respiratory system, four-chambered heart, well developed brain and senses, and amniotic eggs with hard shells.

SC.912.A.11.2 Analyze how birds maintain homeostasis in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes that birds use behavioral, physiological, and structural adaptations to maintain body temperature, water balance, oxygen levels, and energy supply.

SC.912.A.11.3 Examine the adaptations of birds that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes physical and behavioral adaptations that help birds grow, reproduce, and survive.

SC.912.A.11.4 Analyze the unique features of birds.

Benchmark Clarifications:

Clarification 1: Instruction includes the integumentary, nervous, skeletal, and respiratory systems.

SC.912.A.11.5 Examine the types and functions of bird feathers.

Benchmark Clarifications:

Clarification 1: Instruction includes the types of bird feathers: contour, flight, down, semiplume, filoplume, and bristle.

SC.912.A.11.6 Determine the role of birds in biogeochemical cycles.

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Benchmark Clarifications:

Clarification 1: Instruction includes the role of birds in nutrient cycling, carbon cycling, seed dispersal, and nutrient transport.

SC.912.A.11.7 Analyze the impact of migration and movement on birds.

Benchmark Clarifications:

Clarification 1: Instruction includes the energy demands of migration and fat storage within birds.

Clarification 2: Instruction includes navigation mechanisms such as the Sun as a compass, magnetic fields, and landmarks.

Clarification 3: Instruction includes the impacts of stop-over sites, barriers, and habitat connections.

Clarification 4: Instruction includes interpreting migration maps, population datasets, and tracking studies to evaluate movement patterns and population connectivity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using migration maps and ecological models to explain bird movement and habitat connectivity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.11.8 Analyze the role of birds in transferring energy between lower-level producers and higher-level predators.

Benchmark Clarifications:

Clarification 1: Instruction includes trophic roles of birds as herbivores, carnivores, omnivores, scavengers, and insectivores.

Clarification 2: Instruction includes that birds transfer energy among trophic levels and connect terrestrial, freshwater, and marine food webs.

Clarification 3: Instruction includes using food-web models to explain the role of birds in energy transfer. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.11.9 Examine the anthropogenic impacts on birds.

Benchmark Clarifications:

Clarification 1: Instruction includes positive impacts such as habitat restoration, wildlife conservation programs and laws, protected management areas, sustainable land use practices, species recovery programs, and public education.

Clarification 2: Instruction includes negative impacts such as habitat loss and fragmentation, pollution and chemical exposure, introduction of invasive species, collisions, disease spread, over exploitation, and toxic bioaccumulation.

SC.912.A.11.10 Examine the impacts of natural disasters on birds.

Benchmark Clarifications:

Clarification 1: Instruction includes natural disasters such as hurricanes, freezing temperatures, flooding, wildfires, and drought.

Clarification 2: Instruction includes short-term displacement and long-term population changes.

SC.912.A.11.11 Analyze the impact of invasive species on birds.

Benchmark Clarifications:

Clarification 1: Instruction includes the impact on both plant and animal invasive species.

Clarification 2: Instruction includes changes to nesting success, food availability, and community structure.

SC.912.A.11.12 Explore the features of birds that determine how they are classified in Kingdom Animalia.

Benchmark Clarifications:

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Clarification 1: Instruction includes characteristics used to classify birds including feathers, beaks, endothermy, amniotic egg development, skeletal adaptations, and body organization.

Clarification 2: Instruction includes distinguishing major bird groups using anatomical, physiological, reproductive, and behavioral characteristics.

Clarification 3: Instruction includes using classification diagrams, cladograms, and comparative anatomical models to classify birds within Kingdom Animalia. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing anatomical observations and classification evidence used to distinguish bird groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.11.13 Analyze how birds have developed behavioral, structural, and physiological adaptations that enable them to survive in various environments.

Benchmark Clarifications:

Clarification 1: Instruction includes behavioral adaptations such as migration, seasonal breeding, nesting strategies, foraging behaviors, social behaviors, flocking or territorial defense, predator avoidance, and activity patterns.

Clarification 2: Instruction includes structural adaptations such as variations in wing shape and size, beak structures adapted to specific diets, claw modifications, feather types, and skeletal adaptations.

Clarification 3: Instruction includes physiological adaptations such as endothermy and thermal regulation, respiratory and circulatory systems to support metabolic demands, water and salt balance mechanisms, energy storage for migration, and metabolic adjustments that support activity in extreme environments.

SC.912.A.11.14 Examine the impact of disease on bird populations.

Benchmark Clarifications:

Clarification 1: Instruction includes analyzing disease prevalence and population-level data to explain disease impacts on bird populations. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 2: Instruction includes evaluating evidence describing disease impacts on bird populations. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.12 Analyze the structural, functional, and ecological characteristics of mammals; and explain their adaptations, body systems, sensory capabilities, modes of reproduction, and roles within terrestrial, freshwater, and marine ecosystems.

SC.912.A.12.1 Examine mammals as a type of vertebrate.

Benchmark Clarifications:

Clarification 1: Instruction includes that mammals are vertebrate, endothermic animals capable of living in terrestrial and aquatic (freshwater and marine) environments.

Clarification 2: Instruction includes defining characteristics of mammals, such as hair or fur, mammary glands that produce milk, a four-chambered heart, lungs for breathing, and a highly developed brain.

Clarification 3: Instruction includes basic mammalian anatomy including an internal bony skeleton, backbone, skull, limbs positioned beneath the body, and complex organ systems.

SC.912.A.12.2 Analyze how mammals maintain homeostasis in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes that mammals use behavioral, physiological, and structural adaptations to regulate body temperature, water balance, oxygen levels, and energy supply.

Clarification 2: Instruction includes thermoregulation through insulation, sweating, panting, shivering, and behavioral responses such as seeking shade or shelter.

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Clarification 3: Instruction includes variation in homeostatic strategies among egg-laying mammals (monotremes), pouch mammals (marsupials), and placental mammals.

Clarification 4: Instruction includes physiological adaptations of marine mammals for osmoregulation, diving, oxygen storage, and thermal regulation.

SC.912.A.12.3 Examine the adaptations of mammals that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes reproductive strategies of egg-laying mammals (monotremes) such as the platypus and echidnas.

Clarification 2: Instruction includes that monotremes lay eggs in protected locations and secrete milk onto the skin rather than nursing from nipples.

Clarification 3: Instruction includes pouch mammals (marsupials) that give birth to underdeveloped young that continue development in a pouch.

Clarification 4: Instruction includes placental mammals, young develop inside the uterus and are nourished by a placenta before birth.

Clarification 5: Instruction includes physical and behavioral adaptations such as limb modification, body shape, insulation, and behavioral flexibility that support survival in various environments.

SC.912.A.12.4 Analyze the unique features of mammals.

Benchmark Clarifications:

Clarification 1: Instruction includes mammalian sensory systems such as eyes, ears, nose, tongue, vestibular system, and skin.

Clarification 2: Instruction includes specialized adaptations such as the tapetum lucidum for enhanced night vision in some mammals.

Clarification 3: Instruction includes the Jacobson’s organ (vomeronasal organ) used by some mammals to detect pheromones.

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SC.912.A.12.5 Determine the role of mammals in biogeochemical cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of mammals in nutrient cycling through feeding, digestion, waste production, and decomposition.

Clarification 2: Instruction includes mammalian contributions to carbon cycling through respiration, biomass accumulation, and trophic interactions.

Clarification 3: Instruction includes ecosystem roles such as seed dispersal, soil disturbance, and nutrient transport across ecosystems.

SC.912.A.12.6 Analyze the impact of migration and movement on mammals.

Benchmark Clarifications:

Clarification 1: Instruction includes seasonal migration, daily movement patterns, and territorial behavior in mammals.

Clarification 2: Instruction includes energy demands, fat storage, and physiological endurance needed to support long-distance movement.

Clarification 3: Instruction includes the influence of barriers, habitat connectivity, and human development on mammalian movement.

Clarification 4: Instruction includes interpreting movement and migration datasets to evaluate population connectivity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes using movement maps and ecological models to explain mammalian migration and habitat connectivity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.12.7 Analyze the role of mammals in transferring energy between lower-level producers and higher-level predators.

Benchmark Clarifications:

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Clarification 1: Instruction includes trophic roles of mammals as herbivores, omnivores, and carnivores.

Clarification 2: Instruction includes how mammals transfer stored energy through food webs and food chains.

SC.912.A.12.8 Examine the anthropogenic impacts on mammals.

Benchmark Clarifications:

Clarification 1: Instruction includes positive impacts such as conservation programs, wildlife protection laws, habitat restoration, sustainable land use, and public education.

Clarification 2: Instruction includes negative impacts such as habitat loss and fragmentation, pollution, climate change, hunting and poaching, vehicle collisions, and disease transmission.

SC.912.A.12.9 Examine the impacts of natural disasters on mammals.

Benchmark Clarifications:

Clarification 1: Instruction includes natural disasters such as hurricanes, floods, droughts, wildfires, and extreme temperatures.

Clarification 2: Instruction includes short-term displacement, injury, mortality, and long-term population and habitat changes.

SC.912.A.12.10 Analyze the impact of invasive species on mammals.

Benchmark Clarifications:

Clarification 1: Instruction includes invasive plant and animal species that alter habitat structure, food availability, and competition.

Clarification 2: Instruction includes impacts on native mammal populations, including predation pressure, disease spread, and ecosystem balance.

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SC.912.A.12.11 Explore the features of mammals that determine how they are classified in Kingdom Animalia.

Benchmark Clarifications:

Clarification 1: Instruction includes skeletal features such as the vertebral column, single lower jawbone, differentiated teeth, and limb structure.

Clarification 2: Instruction includes nervous system development, brain complexity, and reproductive traits as classification criteria.

Clarification 3: Instruction includes using classification diagrams, cladograms, and comparative anatomical models to classify mammals within Kingdom Animalia. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes analyzing anatomical observations and classification evidence used to distinguish mammalian groups. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.12.12 Analyze how mammals have developed behavioral, structural, and physiological adaptations that enable them to survive in aquatic and terrestrial environments.

Benchmark Clarifications:

Clarification 1: Instruction includes behavioral adaptations such as migration, social behavior, parental care, foraging strategies, and communication.

Clarification 2: Instruction includes structural adaptations such as limb specialization, dentition, body covering, and skeletal modifications.

Clarification 3: Instruction includes physiological adaptations such as endothermy, advanced circulatory and respiratory systems, metabolic regulation, and complex brain functions.

SC.912.A.12.13 Examine the impact of disease on mammal populations.

Benchmark Clarifications:

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Clarification 1: Instruction includes how infectious and noninfectious diseases affect mammal survival, reproduction, and population dynamics.

Clarification 2: Instruction includes the spread of disease through populations and the influence of environmental stressors and human activity.

Clarification 3: Instruction includes analyzing disease transmission data and population-level effects. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes evaluating biological evidence linking disease dynamics to mammal population changes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.12.14 Analyze the importance of mammalian teeth.

Benchmark Clarifications:

Clarification 1: Instruction includes the contribution of mammalian teeth to a balanced ecosystem.

Clarification 2: Instruction includes that mammalian teeth are used for eating, defense, grooming, picking up and carrying young, social displays, and tools.

Clarification 3: Instruction includes the connection between specialized mammalian teeth, the mammalian diet, and their body systems.

SC.912.A.12.15 Examine mammary glands as a defining feature of mammals.

Benchmark Clarifications:

Clarification 1: Instruction includes mammalian mammary glands, which are specialized glands found only in mammals that produce milk to nourish and protect their young after birth.

Clarification 2: Instruction includes that mammary glands are an integumentary structure but are hormonally controlled by the endocrine system.

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Proposed DRAFT Standards

SC.912.A.13 Explain how core animal physiological processes, cellular respiration, digestion, circulation, gas exchange, excretion, and neural and hormonal regulation enable survival and productivity; and how these processes drive energy flow, matter cycling, and life supporting functions within ecosystems.

SC.912.A.13.1 Examine animal physiology within an ecosystem.

Benchmark Clarifications:

Clarification 1: Instruction includes the connection of animal physiology to: the carbon cycle, oxygen use, food webs and trophic levels, biomass accumulation, nutrient recycling, and the flow of energy through ecosystems.

SC.912.A.13.2 Examine cellular respiration as a central physiological process that keeps animals alive, functional, and active.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals use glucose and oxygen to produce adenosine triphosphate (ATP), carbon dioxide, and water.

Clarification 2: Instruction includes that adenosine triphosphate (ATP) powers movement, growth, repair, thermoregulation, and homeostasis.

SC.912.A.13.3 Explain how animal physiology and hormones coordinate to regulate growth, metabolism, reproduction, and behavior.

Benchmark Clarifications:

Clarification 1: Instruction includes animal hormones such as insulin, glucagon, thyroid hormones, adrenaline, epinephrine, estrogen, testosterone, and cortisol.

SC.912.A.13.4 Recall that animals are multicellular organisms that obtain energy by consuming other organisms.

Benchmark Clarifications:

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Clarification 1: Instruction includes that animals are heterotrophs that digest organic molecules to obtain energy and matter.

SC.912.A.13.5 Examine the role of animal physiology in sustaining life.

Benchmark Clarifications:

Clarification 1: Instruction includes that animal physiological systems support movement, feeding, reproduction, defense, and environmental response.

SC.912.A.13.6 Examine how adaptations of respiratory surfaces optimize gas exchange in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes adaptations such as lungs, gills, tracheal systems, alveoli, capillary networks, and diffusion surfaces.

SC.912.A.13.7 Analyze the role of the circulatory system in supporting animal metabolism.

Benchmark Clarifications:

Clarification 1: Instruction includes that the circulatory system transports oxygen, nutrients, hormones, and wastes.

Clarification 2: Instruction includes that circulation enables sustained activity and supports cellular respiration throughout the body.

Clarification 3: Instruction includes that circulation connects the functions of all organ systems.

Clarification 4: Instruction includes using systems models to explain interactions among circulatory, respiratory, digestive, and cellular processes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.13.8 Analyze the role of the digestive system in feeding cellular respiration in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes that digestion breaks down food into glucose, amino acids, fatty acids, vitamins, and minerals that are then used by cells.

SC.912.A.13.9 Explain the role of gas exchange regulation in maintaining metabolic balance in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals must balance oxygen uptake with carbon dioxide removal.

Clarification 2: Instruction includes regulation through breathing rate, heart rate, blood oxygen levels, and the activity level of the animal.

SC.912.A.13.10 Examine the relationship between cellular specialization and metabolic demand in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes that muscle cells, neurons, liver cells, and epithelial cells have structural differences reflecting energy needs.

Clarification 2: Instruction includes that cells with high energy demand contain more mitochondria.

Clarification 3: Instruction includes analyzing cellular and metabolic data to compare energy demands among specialized cell types. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.13.11 Identify hormonal and neural controls that influence metabolic efficiency of animals.

Benchmark Clarifications:

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Clarification 1: Instruction includes regulation by the nervous system and endocrine system acting together to adjust metabolism.

SC.912.A.13.12 Determine how cellular respiration drives physiological adaptations of animals.

Benchmark Clarifications:

Clarification 1: Instruction includes adaptations that maximize oxygen delivery, nutrient distribution, and waste removal.

SC.912.A.13.13 Analyze cellular respiration as the foundation of all animals' physiological processes.

Benchmark Clarifications:

Clarification 1: Instruction includes that adenosine triphosphate (ATP) produced by cellular respiration powers all cellular and system-level functions.

SC.912.A.13.14 Examine how muscles use cellular respiration to produce movement.

Benchmark Clarifications:

Clarification 1: Instruction includes that muscle contraction requires adenosine triphosphate (ATP) for actin-myosin interaction.

Clarification 2: Instruction includes aerobic and anaerobic respiration during sustained and rapid movement.

SC.912.A.13.15 Examine how organs that construct animal body systems use cellular respiration to support growth, repair, and function.

Benchmark Clarifications:

Clarification 1: Instruction includes that organs continuously perform cellular respiration regardless of activity level.

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SC.912.A.13.16 Examine how animal physiological systems are integrated through energy use.

Benchmark Clarifications:

Clarification 1: Instruction includes that no animal system works independently and all are powered by adenosine triphosphate (ATP).

SC.912.A.13.17 Distinguish the roles of digestion, circulation, respiration, and cellular respiration in maintaining homeostasis in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes comparing the functions of digestion, circulation, gas exchange, and cellular respiration in maintaining homeostasis.

Clarification 2: Instruction includes using systems models to explain interactions among organ systems that support homeostasis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.13.18 Analyze cellular respiration as the energy engine of animal physiology.

Benchmark Clarifications:

Clarification 1: Instruction includes that cellular respiration powers movement, sensory processing, neural signaling, temperature regulation, reproduction, and survival.

SC.912.A.14 Explain how animals reproduce through both asexual and sexual strategies, including processes, advantages, and disadvantages of each method.

SC.912.A.14.1 Explain how animals reproduce using both asexual and sexual strategies.

Benchmark Clarifications:

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Clarification 1: Instruction includes the structures involved in animal reproduction, the processes for asexual and sexual animal reproduction.

Clarification 2: Instruction includes the advantages and disadvantages of each reproductive strategy.

SC.912.A.14.2 Examine the types of animal asexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes asexual reproduction methods such as binary fission, budding, fragmentation with regeneration, and parthenogenesis.

SC.912.A.14.3 Examine the steps of animal sexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes the steps of animal sexual reproduction: gamete production, mating or gamete release, fertilization, embryonic development, and birth or hatching.

SC.912.A.14.4 Identify the animals capable of asexual reproduction and the conditions under which it occurs.

Benchmark Clarifications:

Clarification 1: Instruction includes animals capable of asexual reproduction such as hydra, planaria, starfish, aphids, and certain reptiles.

Clarification 2: Instruction includes the environments and biological conditions that are necessary for successful asexual reproduction.

SC.912.A.14.5 Identify the forms of human-directed asexual reproduction in animals.

Benchmark Clarifications:

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Clarification 1: Instruction includes artificial cloning techniques such as somatic cell nuclear transfer.

SC.912.A.14.6 Compare the advantages and disadvantages of asexual reproduction in animals.

SC.912.A.14.7 Examine the role of specialized cells in animal asexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes cell division through mitosis, regeneration, and differentiation.

SC.912.A.14.8 Analyze cloning as a human-directed method of animal reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes that cloned animals are genetically identical to the donor organism.

Clarification 2: Instruction includes ethical and biological considerations of animal cloning.

Clarification 3: Instruction includes evaluating biological evidence used to assess cloning methods and outcomes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.14.9 Examine the role of hormones in regulating animal reproductive processes.

Benchmark Clarifications:

Clarification 1: Instruction includes reproductive hormones such as testosterone, estrogen, progesterone, follicle-stimulating hormone (FSH), and luteinizing hormone (LH).

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SC.912.A.14.10 Explain fragmentation and regeneration as methods of animal reproduction.

SC.912.A.14.11 Identify the reproductive structures involved in animal sexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes male and female reproductive structures such as testes, ovaries, sperm ducts, oviducts, uterus, and external reproductive organs.

SC.912.A.14.12 Determine the role of mating behaviors and fertilization in animal sexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes internal and external fertilization.

Clarification 2: Instruction includes the behavioral and environmental cues that facilitate mating.

SC.912.A.14.13 Examine the types of fertilization and early development of animals.

Benchmark Clarifications:

Clarification 1: Instruction includes zygote formation, cleavage, blastula formation, and gastrulation.

SC.912.A.14.14 Examine egg structure and function in animals that reproduce by laying eggs.

Benchmark Clarifications:

Clarification 1: Instruction includes egg structures: yolk, membranes, shells and embryos.

Clarification 2: Instruction includes the environmental requirements for embryo development such as temperature and oxygen availability.

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SC.912.A.14.15 Analyze how development strategies increase survival and reduce competition in animal populations.

Benchmark Clarifications:

Clarification 1: Instruction includes oviparous, viviparous, and ovoviviparous development.

Clarification 2: Instruction includes levels of parental care and offspring independence.

Clarification 3: Instruction includes comparing survival, reproductive success, and offspring development using quantitative evidence. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 4: Instruction includes comparing survival, reproductive success, and offspring development using observational and experimental evidence. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.14.16 Analyze the role of hormones in regulating animal reproductive cycles.

Benchmark Clarifications:

Clarification 1: Instruction includes hormonal regulation of sexual and asexual reproduction.

Clarification 2: Instruction includes feedback mechanisms in endocrine control systems.

SC.912.A.14.17 Compare offspring development resulting from sexual and asexual animal reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes that sexual reproduction produces genetically unique offspring, while asexual reproduction produces genetically identical offspring.

Clarification 2: Instruction includes differences in development complexity and adaptability.

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SC.912.A.14.18 Distinguish between the advantages and disadvantages of asexual reproduction in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes the advantages of asexual reproduction: rapid population growth and reproduction without a mate.

Clarification 2: Instruction includes the disadvantages of asexual reproduction: reduced genetic diversity and lower adaptability.

SC.912.A.14.19 Distinguish between the advantages and disadvantages of sexual reproduction in animals.

Benchmark Clarifications:

Clarification 1: Instruction includes the advantages of sexual reproduction: increased genetic diversity and enhanced survival in changing environments.

Clarification 2: Instruction includes the disadvantages of sexual reproduction: higher energy demands, longer development times, and the need to find a mate.

SC.912.A.15 Explain how animals interact with their environment and other organisms including their ecological roles, behavioral and physiological adaptations, symbiotic relationships, and responses to biotic and abiotic stressors.

SC.912.A.15.1 Describe how animals interact with their environment and other living things.

Benchmark Clarifications:

Clarification 1: Instruction includes animal roles in energy flow as consumers, contributions to biogeochemical cycles, basic structural and behavioral adaptations, and human impacts on animal populations.

Clarification 2: Instruction includes animal responses to biotic and abiotic stressors such as predation, disease, competition, temperature, water availability, and habitat alteration.

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SC.912.A.15.2 Explain how animals interact with their environment, other animals, and other living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes that behavioral, physiological, and morphological adaptations are the bridge between animal survival and environmental conditions.

Clarification 2: Instruction includes that ecological succession demonstrates animal-to-animal, animal-to-plant, and animal-to-environment interactions that shape ecosystems over time.

Clarification 3: Instruction includes population ecology principles explaining how interactions such as predation, competition, and resource availability determine whether animal populations grow, decline, or remain stable.

Clarification 4: Instruction includes advanced adaptations demonstrating how animal survival is tied to interactions and environmental pressures, such as migration, hibernation, camouflage, mimicry, social behaviors, and physiological tolerance mechanisms.

SC.912.A.15.3 Analyze the interactions between animals and other living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes predator-prey dynamics, competition, parasitism, mutualism, commensalism, and host-pathogen interactions.

SC.912.A.15.4 Explain the animal-to-animal interactions that shape population structure and community composition.

Benchmark Clarifications:

Clarification 1: Instruction includes intraspecific and interspecific competition, territoriality, social hierarchies, cooperative behaviors, and mating systems.

Clarification 2: Instruction includes communication mechanisms such as visual displays, chemical signals, acoustic signals, and tactile cues that influence animal interactions.

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SC.912.A.15.5 Explain the strategies animals use to influence plant populations and other animal species.

Benchmark Clarifications:

Clarification 1: Instruction includes herbivory, pollination support, seed dispersal, ecosystem engineering, trophic cascades, and reciprocal adaptation between species.

Clarification 2: Instruction includes behavioral and chemical interactions such as pheromones, alarm signals, and defensive secretions affecting interspecies interactions.

SC.912.A.15.6 Explore the symbiotic relationships between animals and other organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes animal symbioses with microorganisms, plants, and fungi, such as gut microbiomes, cleaning symbioses, and protective mutualisms.

Clarification 2: Instruction includes the ecological consequences of the loss of a symbiotic partner on animal survival and ecosystem stability.

Clarification 3: Instruction includes coral-algal symbioses, cleaning symbioses, and microbial associations that support marine ecosystem structure and function.

Clarification 4: Instruction includes evaluating how changes in allele frequencies may influence population and adaptation and the persistence of traits within populations over time.

SC.912.A.15.7 Analyze the ecosystem interdependence between animals, decomposers, and nutrient cycling.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of animals in nutrient recycling through feeding, waste production, scavenging, and trophic transfer within ecosystems.

Clarification 2: Instruction includes the effects of the loss or decline of animal populations on decomposition rates, nutrient availability, and ecosystem function.

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SC.912.A.15.8 Examine the effects of environmental pollutants on animals.

Benchmark Clarifications:

Clarification 1: Instruction includes common pollutants such as pesticides, heavy metals, plastics, endocrine disruptors, and air and water contaminants.

Clarification 2: Instruction includes bioaccumulation and biomagnification across trophic levels.

Clarification 3: Instruction includes impacts of water, soil, and air pollution on animal physiology and behavior.

Clarification 4: Instruction includes observable effects of pollutants on animal health, reproduction, population dynamics, and community structure.

SC.912.A.16 Explain how animals influence ecosystem productivity through feeding relationships, population regulation, nutrient redistribution, and trophic interactions.

SC.912.A.16.1 Recognize the role of animals in regulating ecosystem productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals influence ecosystem productivity by transferring energy, regulating biomass, and shaping community structure across trophic levels.

Clarification 2: Instruction includes that animal populations do not create energy but control how energy captured by producers moves through ecosystems.

Clarification 3: Instruction includes interpreting food-web, biomass, and productivity models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.16.2 Explain how animals influence the distribution and availability of energy and biomass.

Benchmark Clarifications:

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Clarification 1: Instruction includes that animals influence biomass distribution through feeding behaviors such as grazing, browsing, and predation.

Clarification 2: Instruction includes that animal movement, foraging, and migration redistribute energy and organic matter across ecosystems.

SC.912.A.16.3 Analyze the importance of animals in shaping ecosystem productivity across trophic levels.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals regulate plant biomass and productivity, which in turn affects food availability for higher trophic levels.

Clarification 2: Instruction includes that animal population size and feeding intensity influence the amount of energy transferred upward through food webs.

Clarification 3: Instruction includes analyzing productivity and biomass datasets across trophic levels. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.16.4 Identify the biotic and abiotic factors that influence animal impacts on ecosystem productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes abiotic factors such as climate, water availability, habitat structure, and disturbance regimes that affect animal feeding and population dynamics.

Clarification 2: Instruction includes biotic factors such as competition, predation, disease, and resource availability that alter animal influence on productivity.

Clarification 3: Instruction includes human-driven factors (anthropogenic) such as habitat loss, hunting, invasive species introduction, land use change, and shifts in temperature and precipitation patterns.

SC.912.A.16.5 Analyze the effects of grazing and browsing pressures on ecosystem productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes that grazing and browsing animals regulate plant biomass, species composition, and rates of primary production.

Clarification 2: Instruction includes that overgrazing and under-grazing can both destabilize ecosystems and reduce productivity.

SC.912.A.16.6 Examine how keystone predators and ecosystem engineers influence ecosystem productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes keystone predators whose effects on productivity are disproportionate to their population size.

Clarification 2: Instruction includes ecosystem engineers, such as burrowing animals or habitat-modifying species, that alter resource availability, nutrient distribution, and habitat structure.

SC.912.A.16.7 Explain how trophic cascades alter ecosystem productivity and stability.

Benchmark Clarifications:

Clarification 1: Instruction includes that trophic cascades occur when changes in predator populations indirectly affect plant biomass and productivity.

Clarification 2: Instruction includes that trophic cascades demonstrate how animal interactions at higher trophic levels influence ecosystem structure, energy flow, and nutrient cycling.

Clarification 3: Instruction includes using trophic-cascade models to predict ecosystem responses to population changes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.16.8 Analyze the role of animals in nutrient redistribution and ecosystem connectivity.

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Benchmark Clarifications:

Clarification 1: Instruction includes how animals contribute to nutrient redistribution through waste production, carcass decomposition, and feeding across habitats.

Clarification 2: Instruction includes how migration and movement connect terrestrial and aquatic (freshwater and marine) ecosystems and influence productivity at multiple scales.

SC.912.A.16.9 Analyze anthropogenic impacts on animal-mediated ecosystem productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes how changes in animal populations due to hunting, habitat alteration, pollution, and shifts in temperature and precipitation patterns modify ecosystem productivity.

Clarification 2: Instruction includes evaluation of how restoring or removing animal species alters trophic structure and ecosystem function.

Clarification 3: Instruction includes evaluating ecological models describing anthropogenic impacts on ecosystem productivity. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.17 Explain the role of animals in the cycling of matter through ecosystems, including participation in carbon, nitrogen, and phosphorus cycles.

SC.912.A.17.1 Distinguish the role of animals in the movement of essential elements through ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes three major biogeochemical cycles: carbon, nitrogen, and phosphorus.

Clarification 2: Instruction includes that animals do not create elements but redistribute and transform matter through feeding, respiration, waste production, movement, and decomposition.

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SC.912.A.17.2 Determine the animal-specific roles in the carbon cycle.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals consume organic carbon through feeding and transfer carbon through food webs.

Clarification 2: Instruction includes that cellular respiration in animals releases carbon dioxide into the atmosphere or water.

Clarification 3: Instruction includes that animal waste, remains, and carcasses return carbon to soils and sediments through decomposition.

SC.912.A.17.3 Determine the animal-specific roles in the nitrogen cycle.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals obtain nitrogen by consuming plants or other animals and incorporate it into tissues.

Clarification 2: Instruction includes that animals return nitrogen to ecosystems through excretion, waste production, and decomposition.

Clarification 3: Instruction includes that animal waste products support microbial processes such as ammonification, nitrification, and denitrification.

SC.912.A.17.4 Determine the animal-specific roles in the phosphorus cycle.

Benchmark Clarifications:

Clarification 1: Instruction includes that animals acquire phosphorus through feeding and use it for skeletal structures, cellular membranes, and energy transfer molecules.

Clarification 2: Instruction includes that animals return phosphorus to soils, sediments, and aquatic systems through waste, decomposition, and trophic transfer.

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SC.912.A.17.5 Examine how animal movement influences the redistribution of nutrients across ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes migration, dispersal, and foraging behavior that transport nutrients across landscapes and between ecosystems.

Clarification 2: Instruction includes marine-terrestrial nutrient transfer, such as nutrients moved by migratory fish, seabirds, or marine mammals, which connect ocean and land nutrient cycles.

Clarification 3: Instruction includes using maps and migration datasets to analyze nutrient redistribution across ecosystems. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.17.6 Analyze the role of animals in linking consumers, decomposers, and nutrient availability.

Benchmark Clarifications:

Clarification 1: Instruction includes that animal remains and waste provide organic matter to decomposers, facilitating nutrient recycling.

Clarification 2: Instruction includes that animals influence the rate and location of decomposition, shaping nutrient availability for producers.

Clarification 3: Instruction includes evaluating evidence describing relationships among consumers, decomposers, and nutrient availability. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.18 Explain how animals respond to, influence, and shape ecological succession through colonization, habitat modification, species interactions, and population shifts.

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SC.912.A.18.1 Describe how animals contribute to ecological succession and community development over time.

Benchmark Clarifications:

Clarification 1: Instruction includes animal responses to both primary and secondary succession, including patterns of colonization, extinction, and community replacement.

Clarification 2: Instruction includes that animal communities change as habitat structure, food availability, and species interactions shift during succession.

Clarification 3: Instruction includes predicting how shifts in vegetative canopy cover alter local microclimates, such as light, temperature, and moisture, driving animal species replacement.

Clarification 4: Instruction includes analyzing quantitative species-richness and biomass datasets across successional stages. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 5: Instruction includes modeling animal community assembly during primary succession compared to secondary succession. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.18.2 Examine the processes by which early successional animal species colonize newly available or disturbed habitats.

Benchmark Clarifications:

Clarification 1: Instruction includes evaluating passive dispersal mechanisms, including wind-driven aerial ballooning and rafting. Clarification 2: Instruction includes active dispersal (flight, migration) in early successional pioneers.

Clarification 3: Instruction includes that early successional animals often tolerate harsh abiotic conditions and limited resources and can survive in simplified habitats.

SC.912.A.18.3 Examine how animal activities influence habitat conditions during succession.

Benchmark Clarifications:

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Clarification 1: Instruction includes animal behaviors such as grazing, browsing, burrowing, predation, and waste deposition that modify vegetation structure, soil properties, and resource availability.

Clarification 2: Instruction includes that animal activities can accelerate, redirect, or slow successional pathways.

SC.912.A.18.4 Explore how disturbance regimes affect animal populations and successional patterns.

Benchmark Clarifications:

Clarification 1: Instruction includes that disturbances are natural or human-driven events that alter animal habitats, resource distribution, and species interactions.

Clarification 2: Instruction includes that disturbances influence animal succession by creating new habitat opportunities, altering competition and predation pressure, and favoring specific adaptations.

Clarification 3: Instruction includes using disturbance and succession models to predict community changes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.18.5 Examine animal resilience as the ability of populations and communities to survive, recover, or reorganize following disturbance.

Benchmark Clarifications:

Clarification 1: Instruction includes that animal resilience determines how quickly species recolonize disturbed areas and how community structure re-establishes over time.

Clarification 2: Instruction includes that resilience is influenced by reproductive strategies, mobility, habitat specialization, population size, and species interactions.

Clarification 3: Instruction includes evaluating evidence describing resilience and recovery following disturbance. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.18.6 Analyze the role of keystone species in shaping successional pathways and long-term community structure.

Benchmark Clarifications:

Clarification 1: Instruction includes keystone predators such as wolves regulating herbivore populations, which indirectly influence plant recovery and succession.

Clarification 2: Instruction includes keystone consumers, such as sea otters controlling sea urchin populations, allowing kelp forests to develop and persist.

Clarification 3: Instruction includes that the removal or reintroduction of keystone species can alter successional trajectories and ecosystem stability.

Clarification 4: Instruction includes evaluating ecological evidence supporting keystone-species designations. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.19 Explain how animal populations grow, stabilize, or decline by examining reproduction, survival, limiting factors, species interactions, carrying capacity, migration, life history strategies, and population models.

SC.912.A.19.1 Recognize that animal population size reflects how well a species survives and reproduces in a given habitat.

Benchmark Clarifications:

Clarification 1: Instruction includes that an animal population is a group of individuals of the same species living in the same area at the same time.

Clarification 2: Instruction includes that animal population size depends on birth rates, death rates, immigration, emigration, and habitat conditions such as food, shelter, and space.

SC.912.A.19.2 Explore the factors that influence animal population growth and survival.

Benchmark Clarifications:

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Clarification 1: Instruction includes abiotic factors such as temperature, water availability, climate conditions, and disturbance events.

Clarification 2: Instruction includes biotic factors such as food availability, predation, disease, competition, and social interactions.

Clarification 3: Instruction includes limiting factors that restrict population growth when resources are finite.

SC.912.A.19.3 Relate carrying capacity to animal population growth and stability.

Benchmark Clarifications:

Clarification 1: Instruction includes that carrying capacity represents the maximum population size an environment can sustain over time.

Clarification 2: Instruction includes that when animal populations exceed carrying capacity, resource depletion, increased competition, and higher mortality rates may occur.

Clarification 3: Instruction includes interpreting population-growth graphs and carrying-capacity models. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.19.4 Explain the interactions among animal species within a given community.

Benchmark Clarifications:

Clarification 1: Instruction includes types of animal species interactions: competition, predation, mutualism, parasitism, and commensalism.

Clarification 2: Instruction includes predator-prey relationships and how population changes in one species influence the population size of another.

SC.912.A.19.5 Analyze how animal populations grow, persist, and change over time through recruitment and survival.

Benchmark Clarifications:

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Clarification 1: Instruction includes that recruitment is the addition of new individuals to a population through birth, immigration, or maturation to reproductive age.

Clarification 2: Instruction includes that recruitment determines population size, age structure, and long-term population viability.

Clarification 3: Instruction includes analyzing recruitment, survivorship, and population-age-structure datasets. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.19.6 Distinguish between density-dependent and density-independent limiting factors affecting animal populations.

Benchmark Clarifications:

Clarification 1: Instruction includes density-dependent factors such as competition, predation, disease, and parasitism that intensify as population size increases.

Clarification 2: Instruction includes density-independent factors such as weather extremes, drought, floods, and habitat destruction that affect populations regardless of size.

SC.912.A.19.7 Use qualitative population models to predict and explain changes in animal populations over time.

Benchmark Clarifications:

Clarification 1: Instruction includes J-curve (exponential growth) and S-curve (logistic growth) population models.

Clarification 2: Instruction includes predator-prey models that demonstrate cyclical population patterns between consumers and their prey.

Clarification 3: Instruction includes interpretation of how limiting factors and carrying capacity shape population trends.

Clarification 4: Instruction includes comparing model predictions with observed population data. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.19.8 Examine how migration and dispersal affect animal population size and distribution.

Benchmark Clarifications:

Clarification 1: Instruction includes that migration adds individuals to some populations while removing individuals from others, altering population size and genetic diversity.

Clarification 2: Instruction includes that seasonal movement connects populations across habitats and influences survival and reproduction.

SC.912.A.19.9 Analyze how life-history strategies influence animal population growth and stability.

Benchmark Clarifications:

Clarification 1: Instruction includes life-history traits such as age at reproduction, number of offspring, parental investment, and lifespan.

Clarification 2: Instruction includes comparisons of strategies that favor rapid reproduction versus those that favor survival and competitive ability.

SC.912.A.19.10 Explore the impact of habitat loss and fragmentation on animal populations.

Benchmark Clarifications:

Clarification 1: Instruction includes the effects of habitat destruction, fragmentation, and degradation on animal population size and connectivity.

Clarification 2: Instruction includes that fragmented habitats reduce migration, increase isolation, and elevate extinction risk.

Clarification 3: Instruction includes analyzing spatial habitat and population datasets to evaluate fragmentation effects. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.A.20 Explain how invasive animal species spread, disrupt ecosystems, alter food webs, and impact native species; and evaluate human activities and management strategies related to their control.

SC.912.A.20.1 Explore the ecological impacts of invasive animal species.

Benchmark Clarifications:

Clarification 1: Instruction includes types of ecological harm caused by invasive animal species such as competition with native species, increased predation pressure, disease transmission, alteration of habitat structure, and disruption of food webs.

SC.912.A.20.2 Determine the impact invasive animal species can have on ecosystem development and stability.

Benchmark Clarifications:

Clarification 1: Instruction includes that invasive animal species can interrupt ecological succession, destabilize established communities, prevent recovery after disturbance, or create alternative community structures that persist over time.

SC.912.A.20.3 Recognize the effects of non-native animal species on soil, plants, animals, water, and ecosystem conditions within a system.

Benchmark Clarifications:

Clarification 1: Instruction includes that invasive animals may alter vegetation through overconsumption, change soil structure through burrowing or trampling, affect water quality, and modify nutrient availability.

Clarification 2: Instruction includes that invasive animals can spread pathogens or parasites that negatively affect native wildlife populations.

SC.912.A.20.4 Describe how invasive animal species disrupt ecosystem processes and biodiversity.

Benchmark Clarifications:

Clarification 1: Instruction includes invasive animal species competition with native species for food, space, and breeding sites.

Clarification 2: Instruction includes increased predation pressure on native species that lack defenses against novel predators.

Clarification 3: Instruction includes changes to ecosystem processes such as altered nutrient cycling, hydrology, or disturbance patterns caused by invasive animal activity.

Clarification 4: Instruction includes reduction in biodiversity when invasive animal species outcompete, prey upon, or transmit disease to native species.

Clarification 5: Instruction includes evaluating evidence describing biodiversity and ecosystem changes resulting from invasive species. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.A.20.5 Explore the mechanisms by which invasive animal species spread.

Benchmark Clarifications:

Clarification 1: Instruction includes human-mediated introductions such as trade, transportation, intentional release, accidental transport, and pet or aquaculture escape.

Clarification 2: Instruction includes natural dispersal mechanisms such as migration, swimming, flight, and movement through connected waterways.

SC.912.A.20.6 Analyze prevention and management strategies used to control invasive animal species.

Benchmark Clarifications:

Clarification 1: Instruction includes prevention strategies such as education, regulation, monitoring, and early detection.

Clarification 2: Instruction includes management strategies such as mechanical removal, chemical control, biological control, habitat restoration, and population reduction efforts.

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Clarification 3: Instruction includes evaluating strengths, limitations, and effectiveness of invasive-species management models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

The Science of Human Body

How cells form tissues and systems, how the human body maintains balance, interacts with its environment, and sustains life through integrated biological processes.

Grades 9-12

SC.912.HB.1 Explain how human cells are organized into tissues, organs, and body systems that work together to maintain life.

SC.912.HB.1.1 Explain how specialized human cells differ in structure and function and how these differences enable cells to perform specific roles within tissues.

Benchmark Clarifications:

Clarification 1: Instruction includes that human cells are specialized through gene expression and differentiation.

Clarification 2: Instruction includes specialized cells such as neurons, muscle cells, epithelial cells, blood cells, and immune cells.

Clarification 3: Instruction includes that cell structure such as shape, organelle abundance, and membrane features reflects functional demand.

Clarification 4: Instruction includes that no single cell can maintain the human body independently.

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SC.912.HB.1.2 Explain how specialized cells are organized into tissues that perform common functions and contribute to the structure and operation of organs in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the primary tissue types: epithelial, connective, muscle, bone, and nervous.

Clarification 2: Instruction includes the structure and function relationships of each tissue type.

Clarification 3: Instruction includes that tissues may be found in multiple organs and organ systems.

Clarification 4: Instruction includes how damage to tissues affects organ function.

SC.912.HB.1.3 Explain how different tissues combine to form organs and how organs work together within human body organ systems to perform complex life functions.

Benchmark Clarifications:

Clarification 1: Instruction includes that organs are composed of multiple tissue types working together.

Clarification 2: Instruction includes organs such as the heart, lungs, stomach, kidneys, brain, and skin.

Clarification 3: Instruction includes that organ systems are groups of organs that perform major body functions.

Clarification 4: Instruction includes that organs often contribute to more than one system.

SC.912.HB.1.4 Explain how human body systems interact and depend on one another to maintain life, internal balance, and responsiveness to the environment.

Benchmark Clarifications:

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Clarification 1: Instruction includes system integration such as circulatory and respiratory systems supplying oxygen; digestive and circulatory systems distributing nutrients; and nervous and muscular systems enabling movement.

Clarification 2: Instruction includes that failure of one human body system can affect multiple others.

Clarification 3: Instruction includes that no body system functions independently.

Clarification 4: Instruction includes that system integration supports homeostasis and survival.

Clarification 5: Instruction includes using systems models to explain interactions among body systems that maintain homeostasis and support survival. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.2 Explain how the human body maintains internal balance through feedback mechanisms involving the nervous, endocrine, and immune systems.

SC.912.HB.2.1 Explain the concept of homeostasis and how feedback mechanisms regulate internal conditions in the human body.

Example: Explain why negative feedback is the primary way the human body maintains homeostasis.

Example: Identify one biological process that is an example of positive feedback and explain why it is considered positive feedback.

Example: A person runs outside on a hot day. Their body temperature begins to rise. Explain how a feedback mechanism helps return the body to normal temperature and include evidence from biological processes.

Benchmark Clarifications:

Clarification 1: Instruction includes homeostasis as the maintenance of relatively stable internal conditions despite external change.

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Clarification 2: Instruction includes negative feedback mechanisms as the primary means of maintaining internal balance.

Clarification 3: Instruction includes components of a feedback loop: stimulus, receptor, control center, effector, and response.

Clarification 4: Instruction includes interpreting feedback-loop diagrams and system models used to explain homeostatic regulation. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.2.2 Explain how the nervous system detects changes in internal and external conditions and rapidly coordinates responses to maintain homeostasis in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes sensory receptors detecting changes such as temperature, pressure, pain, and chemical signals.

Clarification 2: Instruction includes the role of the central nervous system in processing information and directing responses.

Clarification 3: Instruction includes how the nervous system regulates exocrine glad activity, such as sweating, to help maintain homeostasis through temperature regulation.

Clarification 4: Instruction includes neurons, neurotransmitters, and electrical signaling.

Clarification 5: Instruction includes that nervous system regulation is fast, short-term, and specific.

SC.912.HB.2.3 Explain how the endocrine system uses hormones to regulate body processes and maintain long-term homeostasis in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes endocrine glands such as the pituitary, thyroid, pancreas, adrenal glands, and gonads.

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Clarification 2: Instruction includes that endocrine responses are slower but longer lasting than nervous responses.

Clarification 3: Instruction includes the negative feedback regulation of hormones such as insulin and glucagon.

Clarification 4: Instruction includes coordination between the endocrine and nervous systems.

Clarification 5: Instruction includes using graphical data to analyze hormone regulation and negative feedback. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.2.4 Explain how the immune system helps maintain internal balance by detecting, responding to, and regulating threats within the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes innate and adaptive immune responses.

Clarification 2: Instruction includes the role of white blood cells, antibodies, and signaling molecules such as cytokines.

Clarification 3: Instruction includes immune tolerance and mechanisms that prevent damage to healthy tissues.

Clarification 4: Instruction includes examples of overactive immune responses such as allergies and autoimmune disease.

Clarification 5: Instruction includes interactions between immune, nervous, and endocrine systems during stress or illness.

Clarification 6: Instruction includes the roles of lymph, lymphatic vessels, and lymph nodes in transporting immune cells, filtering lymph, and supporting immune responses.

SC.912.HB.2.5 Explain how the nervous, endocrine, and immune systems interact through feedback mechanisms and how breakdowns in regulation disrupt homeostasis and lead to disease in humans.

Example: The body’s response to stress involves multiple regulatory systems.

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Identify which systems are involved in the stress response.

Describe how these systems interact to restore balance.

Benchmark Clarifications:

Clarification 1: Instruction includes examples of system integration such as stress responses and inflammation.

Clarification 2: Instruction includes that dysfunction in one regulatory system can affect others.

Clarification 3: Instruction includes that maintaining homeostasis requires continuous communication among systems.

Clarification 4: Instruction includes how lifestyle and environmental factors influence regulatory balance.

Clarification 5: Instruction includes using systems models to explain interactions among nervous, endocrine, and immune systems during maintenance of homeostasis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes evaluating evidence describing interactions among nervous, endocrine, and immune systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.3 Explain how the human body obtains, transforms, transports, stores, and uses energy and matter to support cellular and organismal processes.

SC.912.HB.3.1 Explain how the human body obtains energy and matter from the environment through feeding, digestion, and respiration.

Benchmark Clarifications:

Clarification 1: Instruction includes that humans obtain matter and energy by consuming food and inhaling oxygen.

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Clarification 2: Instruction includes that humans are heterotrophs that rely on organic molecules produced by other organisms.

Clarification 3: Instruction includes the role of the digestive system in acquiring carbohydrates, proteins, lipids, water, vitamins and minerals.

Clarification 4: Instruction includes the role of the respiratory system in obtaining oxygen for cellular respiration.

SC.912.HB.3.2 Explain how cells transform energy and matter through metabolic processes to support cellular function in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the primary process by which chemical energy in glucose is converted into adenosine triphosphate (ATP) through cellular respiration, including the reactants, products, and basic functions of aerobic and anaerobic cellular respiration.

Clarification 2: Instruction includes that mitochondria are the primary site of adenosine triphosphate (ATP) production.

Clarification 3: Instruction includes that adenosine triphosphate (ATP) powers synthesis, transport, movement, and regulation in cells.

Clarification 4: Instruction includes that matter is transformed but conserved during chemical reactions.

Clarification 5: Instruction includes the role of anaerobic energy-producing processes in living organisms and their applications in human society such as fermentation in food production.

Clarification 6: Instruction includes analyzing quantitative data related to cellular respiration, ATP production, and energy use. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes using models to represent energy transformation and ATP production. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.HB.3.3 Explain how the circulatory system transports energy-containing molecules, gases, and materials to and from cells in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the transport of glucose, oxygen, fatty acids, amino acids, hormones, and wastes in the bloodstream.

Clarification 2: Instruction includes that red blood cells transport oxygen and plasma carries dissolved nutrients and signaling molecules.

Clarification 3: Instruction includes that circulation connects digestion, respiration, and cellular respiration.

Clarification 4: Instruction includes diffusion and active transport at capillary-cell interfaces.

SC.912.HB.3.4 Describe the composition and physiology of blood.

Clarification 1: Instruction includes plasma, red blood cells, white blood cells, and platelets.

Clarification 2: Instruction includes the steps in hemostasis, including the mechanism of coagulation and the basis for blood typing and transfusion reactions.

Clarification 3: Instruction includes how blood viscosity and other properties of blood influence its flow through blood vessels.

SC.912.HB.3.5 Explain how the human body stores excess energy and matter for later use and survival.

Benchmark Clarifications:

Clarification 1: Instruction includes storage of energy as glycogen in the liver and muscles and lipids in adipose tissue.

Clarification 2: Instruction includes short-term versus long-term energy storage.

Clarification 3: Instruction includes that stored matter supports growth, repair, and periods of limited intake.

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Clarification 4: Instruction includes hormonal regulation of storage and release such as insulin and glucagon.

Clarification 5: Instruction includes evaluating graphical and quantitative data describing energy storage and use.

Clarification 6: Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.3.6 Explain how energy is used by the human body to support movement, growth, repair, communication, and homeostasis.

Benchmark Clarifications:

Clarification 1: Instruction includes energy use in muscle contraction, neural signaling, biosynthesis, active transport, and thermoregulation.

Clarification 2: Instruction includes that adenosine triphosphate (ATP) is continuously regenerated to meet cellular demands.

Clarification 3: Instruction includes that different tissues have different energy requirements.

Clarification 4: Instruction includes that energy use scales from cellular processes to whole-body activity.

SC.912.HB.3.7 Explain how human body systems work together to manage energy and matter flow while conserving mass and energy.

Benchmark Clarifications:

Clarification 1: Instruction includes integration among digestive, respiratory, circulatory, excretory, endocrine, and muscular systems.

Clarification 2: Instruction includes that energy is transformed, not created, and matter is conserved.

Clarification 3: Instruction includes that waste products such as carbon dioxide, urea, and heat result from energy use.

Clarification 4: Instruction includes feedback regulation of energy availability and metabolic balance.

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Clarification 5: Instruction includes systems models describing movement of energy and matter through the human body. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.4 Explain how the circulatory and respiratory systems transport gases, nutrients, wastes, and signaling molecules to support cellular function and human survival.

SC.912.HB.4.1 Explain the major structures of the circulatory and respiratory systems and how their organization supports transport throughout the human body.

Example: Analyze how thin walls in capillaries and alveoli enable efficient diffusion of gases and materials.

Example: Demonstrate that branching structures and increased surface area improve transport efficiency throughout the body.

Benchmark Clarifications:

Clarification 1: Instruction includes components of the circulatory system: heart, blood, arteries, veins, and capillaries.

Clarification 2: Instruction includes components of the respiratory system: nose, trachea, bronchi, lungs, alveoli, and diaphragm.

Clarification 3: Instruction includes examining how surface area, diffusion distance, and concentration gradients influence transport efficiency.

Clarification 4: Instruction includes the histological structure of respiratory tissues and how their organization supports airflow, airway protection, and gas exchange.

Clarification 5: Instruction includes analyzing quantitative data describing transport efficiency, diffusion, respiratory surfaces, and circulatory structures. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.HB.4.2 Explain how oxygen and carbon dioxide are exchanged and transported by the respiratory and circulatory systems to support cellular respiration in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the movement of oxygen from the air to lungs to blood to body cells.

Clarification 2: Instruction includes the movement of carbon dioxide from cells to blood to lungs to the external environment.

Clarification 3: Instruction includes diffusion driven by concentration gradients at alveoli and tissues.

Clarification 4: Instruction includes the role of hemoglobin in oxygen transport.

Clarification 5: Instruction includes the connection of gas exchange to cellular respiration and energy production.

Clarification 6: Instruction includes interpreting gas-exchange data, oxygen saturation data, and respiratory graphs. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.4.3 Explain how the circulatory system transports nutrients, metabolic waste, and signaling molecules to maintain cellular function and internal balance in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the transport of nutrients such as glucose, amino acids, fatty acids, vitamins, minerals, and water.

Clarification 2: Instruction includes the removal of wastes such as carbon dioxide, urea, and excess ions.

Clarification 3: Instruction includes the transport of hormones and signaling molecules to target tissues.

Clarification 4: Instruction includes that blood plasma serves as the medium for dissolved substances.

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Clarification 5: Instruction includes capillary exchange via diffusion and active transport.

SC.912.HB.4.4 Explain how the circulatory and respiratory systems function as an integrated unit to meet the metabolic demands of the human body.

Example: Explain the major structures of the circulatory and respiratory systems and how their organization supports transport throughout the human body.

Example: List the major structures of the respiratory system in the order that air passes through them and explain how this system supports oxygen delivery to the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the coordination of breathing rate and heart rate in response to activity or stress.

Clarification 2: Instruction includes that the integration of the circulatory and respiratory systems ensures continuous delivery of oxygen and removal of carbon dioxide while supporting transport of nutrients and wastes throughout the body.

Clarification 3: Instruction includes diffusion across alveoli and capillary membranes.

Clarification 4: Instruction includes that oxygen delivery and carbon dioxide removal are necessary to maintain cellular respiration.

Clarification 5: Instruction includes normal heart sounds and their relationship to valve closure during the cardiac cycle.

SC.912.HB.4.5 Explain how effective transport supports homeostasis and how disruptions in transport impair cellular function and the survival of a human.

Benchmark Clarifications:

Clarification 1: Instruction includes examples of disrupted transport such as restricted blood flow or impaired gas exchange.

Clarification 2: Instruction includes consequences such as reduced adenosine triphosphate (ATP) production, waste buildup, and tissue damage.

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Clarification 3: Instruction includes homeostatic regulation of blood pressure, heart rate, and breathing rate.

Clarification 4: Instruction includes the links between transport function, disease, and overall health.

Clarification 5: Instruction includes the components of an electrocardiogram and interpreting patterns of cardiac electrical activity to explain how abnormalities can affect heart function and blood circulation.

Clarification 6: Instruction includes evaluating evidence linking transport-system dysfunction to disease. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.5 Explain how digestive, urinary, and integumentary systems acquire nutrients, regulate water and ion balance, and eliminate wastes to maintain internal stability of humans.

SC.912.HB.5.1 Explain how the digestive system breaks down food, absorbs nutrients, and delivers energy-rich and essential materials to the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes mechanical and chemical digestion and the neural and hormonal mechanisms that regulate digestive processes.

Clarification 2: Instruction includes the role of digestive organs such as the mouth, stomach, small intestine, pancreas, liver and large intestine.

Clarification 3: Instruction includes absorption of glucose, amino acids, fatty acids, vitamins, minerals, and water by the intestines.

Clarification 4: Instruction includes that digestion provides the raw materials needed for cellular respiration, growth, and repair.

Clarification 5: Instruction includes the histological structure of the alimentary canal and accessory digestive organs and how specialized tissues support digestion, secretion, and nutrient absorption.

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SC.912.HB.5.2 Explain how the urinary system regulates water, electrolyte, and pH balance to maintain internal stability in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the structure and function of the kidneys, nephrons, ureters, bladder, and urethra.

Clarification 2: Instruction includes the physiological processes involved in urine formation within the kidneys, including filtration, reabsorption, and secretion.

Clarification 3: Instruction includes the regulation of water, sodium, potassium, and hydrogen ions.

Clarification 4: Instruction includes that maintaining proper fluid and ion balance is essential for nerve function, muscle contraction, and blood pressure.

Clarification 5: Instruction includes the histological features of the ureters, urinary bladder, and urethra and how their tissues support urine transport, storage, and elimination.

Clarification 6: Instruction includes interpreting data related to kidney function, water balance, and electrolyte regulation. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.5.3 Explain how the digestive and urinary systems remove metabolic wastes to prevent harmful buildup in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes the elimination of solid waste through the digestive tract.

Clarification 2: Instruction includes the elimination of nitrogen waste (urea) through the urinary system.

Clarification 3: Instruction includes that incomplete waste removal disrupts cellular function and homeostasis.

Clarification 4: Instruction includes that waste elimination is essential for a human to survive.

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SC.912.HB.5.4 Explain how the integumentary system contributes to protection, temperature regulation, and limited waste removal in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes structural components of the integumentary system: skin layers, sweat glands, oil glands, hair, and nails.

Clarification 2: Instruction includes that sweat glands aid in temperature regulation and water balance.

Clarification 3: Instruction includes that the skin acts as a barrier against pathogens and dehydration.

Clarification 4: Instruction includes excretion of salts and wastes through perspiration.

SC.912.HB.5.5 Explain how the digestive, urinary, and integumentary systems work together to maintain internal stability in the human body.

Example: Create a labeled visual representation (diagram, flowchart, or concept map) that shows how two or more of the following systems work together to maintain internal stability:

Digestion supplying nutrients → circulation → cellular use

Urinary regulation maintaining blood volume and ion balance

Integumentary regulation controlling temperature and water loss

Example: In 2-3 sentences, explain why maintaining internal stability requires coordination among multiple systems, and describe how failure in one system impacts the others.

Benchmark Clarifications:

Clarification 1: Instruction includes that imbalance in one system affects the other systems.

Clarification 2: Instruction includes that homeostasis depends on coordinated system function.

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Clarification 3: Instruction includes constructing and evaluating systems models of human homeostasis. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6 Explain how the musculoskeletal and nervous systems enable movement, stability, communication, and interaction with the environment in the human body.

SC.912.HB.6.1 Explain how bones, muscles, joints, and connective tissues work together to produce movement and maintain body support and stability.

Benchmark Clarifications:

Clarification 1: Instruction includes the roles of bones, skeletal muscles, tendons, ligaments, and joints.

Clarification 2: Instruction includes that bones provide structure, protection, and attachment points for muscles.

Clarification 3: Instruction includes that skeletal muscles contract and relax to move bones at joints.

Clarification 4: Instruction includes that movement results from muscle pairs (antagonistic muscles) acting across joints.

SC.912.HB.6.2 Distinguish between the axial skeleton and the appendicular skeleton.

Clarification 1: Instruction includes identifying the major bones of the axial and appendicular skeleton on a model or diagram.

Clarification 2: Instruction includes major markings on a skeleton, such as foramina, fossae, tubercles, and why these markings are important.

Clarification 3: Instruction includes using models to explain how the axial and appendicular skeleton work together to maintain body support. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.HB.6.3 Identify the major muscles of the human body.

Clarification 1: Instruction includes using models and diagrams to explain how the muscles of the human body work together to support posture, stabilize joints, and enable movement. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6.4 Distinguish between the central and peripheral nervous systems.

Clarification 1: Instruction includes identifying the major divisions of the nervous system, including the central nervous system and the peripheral nervous system and its somatic and autonomic divisions.

Clarification 2: Instruction includes the anatomy, histology, and physiology of the central and peripheral nervous systems.

Clarification 3: Instruction includes the major functions of the sympathetic and parasympathetic nervous systems and their roles in regulating involuntary body functions.

Clarification 4: Instruction includes using models and diagrams to explain how the central and peripheral nervous systems of the human body work together to receive sensory information, coordinate responses, and control body movement. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6.5 Identify the functions of the major parts of the brain.

Clarification 1: Instruction includes meninges, medulla, pons, midbrain, hypothalamus, cerebellum, and cerebrum.

Clarification 2: Instruction includes using models and diagrams to identify the major parts of the brain and explain their functions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6.6 Identify the major functions of the spinal cord.

Clarification 1: Instruction includes identifying the major parts of a cross section through the spinal cord.

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Clarification 2: Instruction includes using models and diagrams to identify the major parts of the brain and explain their functions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6.7 Explain how muscle cells use energy to contract, generate force, and support movement and posture.

Benchmark Clarifications:

Clarification 1: Instruction includes that muscle contraction requires adenosine triphosphate (ATP).

Clarification 2: Instruction includes the interaction of actin and myosin filaments.

Clarification 3: Instruction includes the differences between voluntary (skeletal) and involuntary (smooth and cardiac) muscle control.

Clarification 4: Instruction includes that muscle tone contributes to posture and stability even when no visible movement occurs.

Clarification 5: Instruction includes how motor neurons stimulate skeletal muscle fibers at the neuromuscular junction to initiate muscle contraction.

Clarification 6: Instruction includes relating ATP demand to muscle performance and activity level using quantitative data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6.8 Explain the physiology of skeletal muscle.

Clarification 1: Instruction includes the organization of skeletal muscle fibers, myofibrils, and sarcomeres.

Clarification 2: Instruction includes the mechanisms by which skeletal muscle fibers contract and relax.

SC.912.HB.6.9 Explain how the nervous system detects stimuli, processes information, and sends signals that control movement, coordination, and responses to the environment.

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Benchmark Clarifications:

Clarification 1: Instruction includes the structures and functions of sensory organs and receptors and how their specialized structures enable the detection of stimuli, including light, sound, chemicals, temperature, and touch.

Clarification 2: Instruction includes sensory neurons, interneurons, and motor neurons and their roles in transmitting and processing information.

Clarification 3: Instruction includes generator potentials, action potentials, and electrical and chemical signaling across neurons and synapses.

Clarification 4: Instruction includes the role of the brain and spinal cord in integrating sensory information and coordinating responses.

Clarification 5: Instruction includes identifying the components of a reflex arc and explaining how they enable rapid, automatic responses to environmental stimuli.

SC.912.HB.6.10 Explain how feedback mechanisms involving the nervous and musculoskeletal systems enable coordination, balance, and precise movement in the human body.

Example: How does your body stay balanced and precise when you move?

Example: Select one of the following everyday actions:

Walking across an uneven surface

Catching a ball thrown unexpectedly

Standing on one foot with your eyes closed

For your selected movement, identify and explain how information from your eyes (vision), inner ear (vestibular system), and proprioceptors (muscles and joints) contributes to coordination and balance.

Benchmark Clarifications:

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Clarification 1: Instruction includes sensory input from eyes, inner ear (vestibular system), and proprioceptors in muscles and joints.

Clarification 2: Instruction includes feedback that allows the body to adjust muscle activity during movement.

Clarification 3: Instruction includes that coordination reduces injury and maintains stability.

Clarification 4: Instruction includes using feedback and sensory-system models to explain balance and coordination. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.6.11 Explain how the musculoskeletal and nervous systems allow the human body to communicate, respond to challenges, and interact effectively with the environment.

Benchmark Clarifications:

Clarification 1: Instruction includes expressive movements such as facial expressions, gestures, speech, and posture.

Clarification 2: Instruction includes voluntary and involuntary responses to environmental changes.

Clarification 3: Instruction includes how sensory-motor integration supports survival tasks such as avoiding danger and acquiring resources.

Clarification 4: Instruction includes that movement and communication depend on precise timing and system integration.

SC.912.HB.6.12 Explain how the integration of the musculoskeletal and nervous systems supports survival and how disruptions impair movement, coordination, and communication in humans.

Example: Analyze a real-world scenario involving injury or system disruption and explain how it affects movement, balance or communication in the body.

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Select one of the following situations:

A person damages a nerve in their arm

A person breaks a leg bone

A person experiences extreme muscle fatigue

A person has a neurological disorder affecting movement

For the selected scenario, answer the following questions:

Which part of the musculoskeletal system is affected?

Which part of the nervous system is affected or must compensate for the situation?

Benchmark Clarifications:

Clarification 1: Instruction includes that impairment in one system affects the function of the other.

Clarification 2: Instruction includes the connection to fatigue, injury, or neurological disorders.

Clarification 3: Instruction includes that effective movement requires continuous coordination between systems.

Clarification 4: Instruction includes evaluating evidence describing effects of injury and disease on system integration. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.7 Explain how the immune system protects the human body from pathogens, how breakdowns in regulation lead to disease, and how advances in biology are used to support disease prevention and treatment.

SC.912.HB.7.1 Explain how the human immune system detects and defends against pathogens using physical barriers and cellular and molecular responses.

Benchmark Clarifications:

Clarification 1: Instruction includes pathogens such as bacteria, viruses, fungi, and parasites.

Clarification 2: Instruction includes physical and chemical barriers such as skin, mucus, stomach acid, and enzymes.

Clarification 3: Instruction includes immune cells such as white blood cells that recognize and respond to foreign substances.

Clarification 4: Instruction includes that immune defenses act continuously to protect the body from infection.

Clarification 5: Instruction includes the role of antibiotics in treating bacterial infections and how antibiotics differ from immune responses and are ineffective against viruses.

SC.912.HB.7.2 Explain the roles of innate and adaptive immune responses and how they differ in speed, specificity, and memory in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes innate immunity as rapid, non-specific defense such as inflammation and phagocytosis.

Clarification 2: Instruction includes adaptive immunity as targeted defense involving B cells, T cells, and antibodies.

Clarification 3: Instruction includes that adaptive immunity produces immune memory for an increased speed of future system responses.

Clarification 4: Instruction includes that both the innate and adaptive immune responses work together to protect the human body.

SC.912.HB.7.3 Explain how feedback mechanisms regulate immune responses to eliminate pathogens while limiting damage to healthy tissues.

Benchmark Clarifications:

Clarification 1: Instruction includes immune signaling molecules such as cytokines that coordinate immune responses.

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Clarification 2: Instruction includes that immune system activation must be turned on or turned off at appropriate times.

Clarification 3: Instruction includes the coordination between the immune, nervous, and endocrine systems during stress or illness.

Clarification 4: Instruction includes that proper regulation of immune responses maintains homeostasis in humans.

Clarification 5: Instruction includes feedback models that regulate activation and suppression of immune responses. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.7.4 Explain how failures in immune regulation may lead to disease and increased health risk in humans.

Example: A patient has a condition in which their immune system remains activated even when no infection is present. This causes long-term inflammation that damages joints and surrounding tissues, leading to pain, stiffness, and reduced mobility. Explain how chronic inflammation results from a failure in immune regulation and describe how an overactive immune response increases health risks by damaging healthy tissues.

Benchmark Clarifications:

Clarification 1: Instruction includes autoimmune diseases, allergies, and immunodeficiency disorders.

Clarification 2: Instruction includes that underactive immunity increases the susceptibility of humans to infections.

Clarification 3: Instruction includes that overactive immunity damages healthy human tissues.

Clarification 4: Instruction includes evaluating evidence linking immune dysregulation to disease outcomes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.HB.7.5 Explain how immune memory supports long-term protection and how human actions influence immune system function and health.

Benchmark Clarifications:

Clarification 1: Instruction includes immune memory responses generated by prior exposure or vaccination.

Clarification 2: Instruction includes that vaccines stimulate immune memory without causing disease.

Clarification 3: Instruction includes lifestyle and environmental factors such as nutrition, stress, sleep, exercise, and exposure to pathogens.

Clarification 4: Instruction includes public health strategies that reduce disease and support immune protection.

Clarification 5: Instruction includes interpreting population and health data related to vaccination and disease prevention. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to immunology, vaccination, immune memory, and disease prevention and how scientific explanations have changed as new evidence became available. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.7.6 Analyze how biotechnology is used to develop biological products for disease prevention and treatment.

Example: Investigate the development and production of recombinant insulin.

Example: Evaluate the use of monoclonal antibodies in disease treatment.

Example: Compare different vaccine technologies.

Benchmark Clarifications:

Clarification 1: Instruction includes vaccine development and production.

Clarification 2: Instruction includes monoclonal antibody technologies.

Clarification 3: Instruction includes recombinant protein production.

Clarification 4: Instruction includes therapeutic applications of biological products in disease prevention and treatment.

Clarification 5: Instruction includes evaluating scientific evidence used to assess the safety and effectiveness of biomedical products. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.8 Explain how the human body reproduces, develops, and changes across the lifespan through coordinated genetic, cellular, and physiological processes.

SC.912.HB.8.1 Explain how human reproduction passes genetic information from one generation to the next through specialized cells and coordinated physiological processes.

Benchmark Clarifications:

Clarification 1: Instruction includes the anatomy and physiology of the human reproductive systems and sexual reproduction through the formation of sperm and eggs (gametes).

Clarification 2: Instruction includes meiosis as the cellular process that produces gametes with half the genetic material.

Clarification 3: Instruction includes fertilization as the union of sperm and egg to form a genetically unique zygote.

Clarification 4: Instruction includes that reproduction ensures genetic continuity and variation within human populations.

SC.912.HB.8.2 Explain how cell division and differentiation guide human growth and development from a single cell into a multicellular organism.

Benchmark Clarifications:

Clarification 1: Instruction includes mitosis as the process for growth and tissue development.

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Clarification 2: Instruction includes stages of prenatal development, including the zygote, embryo, and fetus, and major developmental changes from fertilization through birth.

Clarification 3: Instruction includes that cell differentiation produces specialized cells, tissues, and organs.

Clarification 4: Instruction includes that gene expression controls developmental patterns.

SC.912.HB.8.3 Explain how genetic information and gene regulation influence human development and variation.

Benchmark Clarifications:

Clarification 1: Instruction includes that all body cells contain the same deoxyribonucleic acid (DNA) but express genes differently.

Clarification 2: Instruction includes the role of regulatory genes and signaling pathways in development.

Clarification 3: Instruction includes that genetic variation contributes to differences in traits and development.

Clarification 4: Instruction includes the role of mutations or genetic disorders in altered human development.

Clarification 5: Instruction includes using conceptual models to explain gene regulation and development. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.8.4 Explain how hormones and physiological systems regulate growth, development, and reproductive function through the human lifespan.

Benchmark Clarifications:

Clarification 1: Instruction includes endocrine system regulation of growth and development.

Clarification 2: Instruction includes hormones such as growth hormone, thyroid hormones, estrogen, testosterone, and progesterone.

Clarification 3: Instruction includes feedback mechanisms that regulate hormone levels.

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Clarification 4: Instruction includes coordination among body systems to support reproductive maturation.

SC.912.HB.8.5 Explain how the developing fetus is supported and regulated during prenatal development.

Benchmark Clarifications:

Clarification 1: Instruction includes the role of the placenta, umbilical cord, and amniotic fluid.

Clarification 2: Instruction includes nutrient, gas, and waste exchange between mother and fetus.

Clarification 3: Instruction includes protection of the developing fetus and limits of that protection.

Clarification 4: Instruction includes how environmental factors can influence prenatal development.

Clarification 5: Instruction includes fetal circulation and the changes in blood flow that occur at birth.

Clarification 6: Instruction includes major developmental changes during each trimester of pregnancy.

Clarification 7: Instruction includes evaluating evidence describing environmental influences on prenatal development. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.8.6 Explain how the human body changes structurally and functionally across the lifespan.

Benchmark Clarifications:

Clarification 1: Instruction includes stages such as infancy, childhood, adolescence, adulthood, and aging.

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Clarification 2: Instruction includes physical, hormonal, and physiological changes at different life stages.

Clarification 3: Instruction includes that aging involves gradual changes in cell repair, system efficiency, and regulation.

Clarification 4: Instruction includes variability in lifespan changes among individuals.

SC.912.HB.8.7 Explain how genetics, environment, and lifestyle interact to influence development, reproductive health, and aging.

Benchmark Clarifications:

Clarification 1: Instruction includes nutrition, physical activity, stress, and environmental exposure.

Clarification 2: Instruction includes that early development conditions can influence later health outcomes.

Clarification 3: Instruction includes the role of medical care and public health in reproductive and lifespan health.

Clarification 4: Instruction includes that development and aging are influenced by both biological and environmental factors.

Clarification 5: Instruction includes hypertension and factors that cause it.

Clarification 6: Instruction includes analyzing datasets and case studies describing interactions among genetics, environment, and lifestyle factors. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.9 Explain how the human body interacts with environmental factors, including physical activity, pathogens, pollutants, and lifestyle choices; and how these interactions affect health.

SC.912.HB.9.1 Explain how the human body interacts with environmental factors and how these interactions affect health.

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Example: Analyze nutrition as an environmental factor, focusing on how macronutrients (carbohydrates, proteins, and lipids) and micronutrients (vitamins and minerals) interact with the digestive, endocrine, immune, nervous, and musculoskeletal systems. Calculate total daily calorie intake, percent of calories from each macronutrient, and compare micronutrient amounts to recommended daily values (RDAs) using nutrition labels or provided data. Use your calculations to explain the resulting physiological, behavioral, and cellular responses, and determine whether the health outcomes are adaptive, neutral, or harmful based on the duration and intensity of nutrient exposure.

Benchmark Clarifications:

Clarification 1: Instruction includes environmental factors: physical activity, nutrition, pathogens, pollutants, stress, and lifestyle behaviors.

Clarification 2: Instruction includes that environmental inputs interact with multiple body systems: nervous, immune, respiratory, digestive, endocrine, and musculoskeletal systems.

Clarification 3: Instruction includes that the body responds to environmental conditions through physiological, behavioral, and cellular adjustments.

Clarification 4: Instruction includes that environmental exposure can produce adaptive, neutral, or harmful outcomes depending on duration and intensity.

Clarification 5: Instruction includes quantitative evaluation of nutrition labels, dietary intake, and recommended daily values. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.9.2 Explain how physical activity influences body system function, regulation, and overall health.

Benchmark Clarifications:

Clarification 1: Instruction includes the effects of physical activity on muscular strength, cardiovascular efficiency, respiration, metabolism, and nervous system coordination.

Clarification 2: Instruction includes that regular activity supports energy balance, circulation, immune function, and mental health.

Clarification 3: Instruction includes that inactivity increases risk for chronic diseases, including hypertension, cardiovascular disease, and type 2 diabetes.

Clarification 4: Instruction includes short-term and long-term physiological adaptations to activity.

Clarification 5: Instruction includes interpreting physiological data collected before, during, and after exercise. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.9.3 Explain how exposure to pathogens triggers immune responses and influences human health.

Benchmark Clarifications:

Clarification 1: Instruction includes how pathogens enter the body and interact with immune, respiratory, digestive, and integumentary systems.

Clarification 2: Instruction includes immune defense, recovery, and development of immune memory.

Clarification 3: Instruction includes factors that influence susceptibility, such as stress, nutrition, sleep, and prior exposure.

Clarification 4: Instruction includes prevention strategies such as hygiene, vaccination, and public health measures.

SC.912.HB.9.4 Examine how pollutants and environmental hazards affect human body systems and increase health risks.

Benchmark Clarifications:

Clarification 1: Instruction includes exposure to air, water, and soil pollutants, including chemicals, particulates, and toxins.

Clarification 2: Instruction includes impacts on human body systems: respiratory, nervous, immune, and endocrine systems.

Clarification 3: Instruction includes bioaccumulation and long-term exposure risks.

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Clarification 4: Instruction includes that vulnerability varies by age, health status, and exposure duration.

Clarification 5: Instruction includes evaluating scientific evidence describing the health effects of environmental pollutants. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.9.5 Explain how lifestyle choices influence body system regulation, disease risk, and overall health across the lifespan of a human.

Benchmark Clarifications:

Clarification 1: Instruction includes choices related to diet, sleep, stress management, substance use, and physical activity.

Clarification 2: Instruction includes that lifestyle behaviors can strengthen or weaken regulatory systems.

Clarification 3: Instruction includes the cumulative effects of repeated behaviors over time.

SC.912.HB.9.6 Explain how the integration of human body systems supports resilience to environmental challenges and how disruption increases disease risk.

Example: Analyze poor nutrition or a specific nutrient deficiency as an environmental challenge and explain how the integration of multiple human body systems supports resilience and maintains health. Describe how disruption of this system integration increases the risk of disease or health disorders.

Benchmark Clarifications:

Clarification 1: Instruction includes multiple human body systems: digestive, immune, endocrine, nervous, circulatory, musculoskeletal, respiratory, and integumentary systems.

Clarification 2: Instruction includes systems models explaining resilience and adaptation to environmental challenges. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.HB.9.7 Explain how the structures and chemical properties of biological macromolecules support their functions in living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes the structures and functions of monosaccharides, disaccharides, and polysaccharides, including their roles in energy storage, energy use, and structural support.

Clarification 2: Instruction includes the structures and functions of fatty acids, triglycerides, phospholipids, and steroids, including their roles in energy storage, insulation, cell membranes, and hormone signaling.

Clarification 3: Instruction includes the structures and functions of amino acids and proteins, including how amino acid sequences and protein folding contribute to protein function.

Clarification 4: Instruction includes dehydration synthesis and hydrolysis and how these reactions build and break down biological molecules.

Clarification 5: Instruction includes how enzymes act as catalysts by lowering the activation energy of biochemical reactions and how factors such as temperature and pH affect enzyme activity.

Clarification 6: Instruction includes how the arrangement of hydrophilic and hydrophobic regions in phospholipids contributes to the formation and function of cell membranes.

SC.912.HB.10 Explain how the human body depends on living systems for energy, materials, and services; and how human health is connected to ecosystem health.

SC.912.HB.10.1 Explain how the human body depends on living systems for energy, materials, and services, and how human health is connected to ecosystem health.

Benchmark Clarifications:

Clarification 1: Instruction includes that humans obtain energy and matter through food webs supported by plants, animals, and microorganisms.

Clarification 2: Instruction includes that plants provide the base of food systems by converting solar energy into chemical energy.

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Clarification 3: Instruction includes that humans rely on living systems for macronutrients, micronutrients, oxygen, and water.

Clarification 4: Instruction includes that the disruption of food systems affects nutrition, energy balance, and health.

SC.912.HB.10.2 Explain how ecosystem services provided by living systems support human health and body function.

Example: Analyze and justify how ecosystem services support respiratory, digestive, immune, and metabolic health by constructing a logical reasoning chain that connects specific services, such as oxygen production, clean water, food production, and disease regulation, to body system function. Apply reasoning skills to determine how reduced availability or reliability of these services would logically increase disease risk or health challenges.

Example: Why might some body systems be more sensitive to ecosystem degradation than others?

Benchmark Clarifications:

Clarification 1: Instruction includes ecosystem services such as oxygen production, water purification, waste decomposition, disease regulation, soil fertility, and food production.

Clarification 2: Instruction includes that ecosystem degradation reduces the availability and reliability of ecosystem services.

Clarification 3: Instruction includes evaluating evidence linking ecosystem services to human health outcomes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.10.3 Explain how microorganisms and biodiversity contribute to human health through ecosystem interactions.

Benchmark Clarifications:

Clarification 1: Instruction includes the roles of microbes in nutrient cycling, decomposition, and mutualistic relationships.

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Clarification 2: Instruction includes the connections between biodiversity and disease regulation.

Clarification 3: Instruction includes that loss of biodiversity can increase disease risk and destabilize food systems.

Clarification 4: Instruction includes indirect effects of ecosystem imbalance on immune system challenges.

SC.912.HB.10.4 Explain how changes to ecosystems influence human health outcomes by altering energy availability, exposure to hazards, and system regulation.

Example: Evaluate how ecosystem protection reduces health risks by maintaining energy availability, limiting exposure to environmental hazards, and stabilizing natural system regulation. Use cause-and-effect reasoning to connect ecosystem protection to outcomes such as respiratory illness, waterborne disease, nutritional deficiency, or stress-related illness.

Benchmark Clarifications:

Clarification 1: Instruction includes ecosystem disruption such as pollution, habitat loss, and species decline.

Clarification 2: Instruction includes links between environmental change and respiratory illness, waterborne disease, nutritional deficiency, and stress-related illness.

Clarification 3: Instruction includes using systems models to predict how ecosystem changes influence human health. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.10.5 Explain how patterns of resource use and land management influence ecosystem health and how sustainable practices support long-term human health.

Benchmark Clarifications:

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Clarification 1: Instruction includes sustainable resource use practices that maintain ecosystem services supporting human health.

Clarification 2: Instruction includes evaluating impacts of land-use decisions on long-term human well-being.

Clarification 3: Instruction includes using systems models to predict how resource-use and land-management decisions influence ecosystem services and long-term human health outcomes.

Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.11 Explain how communities of microorganisms living on and within the human body interact with body systems to support digestion, immune function, metabolism, and overall health.

SC.912.HB.11.1 Describe the human microbiome as an integrated community of microorganisms that interact with multiple human body systems.

Benchmark Clarifications:

Clarification 1: Instruction includes the human microbiome as populations of bacteria, archaea, fungi, and viruses located on and within the human body.

Clarification 2: Instruction includes the microbiome as a functional biological system rather than isolated organisms.

Clarification 3: Instruction includes mutualistic and commensal relationships between microorganisms and human cells.

Clarification 4: Instruction includes the role of the microbiome in maintaining internal balance (homeostasis).

SC.912.HB.11.2 Explain how microorganisms in the digestive tract contribute to digestion and nutrient availability in the human body.

Benchmark Clarifications:

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Clarification 1: Instruction includes gut microorganisms and the breakdown of complex carbohydrates and other indigestible compounds.

Clarification 2: Instruction includes microbial production of vitamins such as vitamin K and certain B vitamins.

Clarification 3: Instruction includes microbial contributions to nutrient absorption and energy availability.

Clarification 4: Instruction includes effects of disrupted gut microbial communities on digestion and nutrient balance.

SC.912.HB.11.3 Explain how interactions between microbial communities and the immune system contribute to immune system development and protection against pathogens.

Benchmark Clarifications:

Clarification 1: Instruction includes interaction between microorganisms and immune system development.

Clarification 2: Instruction includes competition between beneficial microbes and pathogens for space and resources.

Clarification 3: Instruction includes immune cells, microbial populations, and signaling molecules.

Clarification 4: Instruction includes links between microbial imbalance and immune dysregulation such as allergies or chronic inflammation.

SC.912.HB.11.4 Analyze how microbial communities influence metabolism and energy balance in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes microbial influence on energy extraction from food.

Clarification 2: Instruction includes the regulation of fat storage and blood sugar balance associated with microbial activity.

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Clarification 3: Instruction includes microbial metabolites and their roles in hormonal and metabolic signaling pathways.

Clarification 4: Instruction includes the relationship between metabolic health and balanced microbial-human system interactions.

Clarification 5: Instruction includes interpreting microbiome and metabolic datasets. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.HB.11.5 Evaluate how balance or disruption of the human microbiome affects overall health and body system function.

Example: A patient is prescribed a broad-spectrum antibiotic to treat a bacterial infection. While the infection improves, the patient later experiences persistent diarrhea, fatigue, and increased susceptibility to illness. Evaluate how the antibiotic reduced not only harmful bacteria but also beneficial gut microorganisms, leading to microbiome dysbiosis.

Benchmark Clarifications:

Clarification 1: Instruction includes microbiome balance as supportive of digestion, immunity, metabolism, and system regulation.

Clarification 2: Instruction includes dysbiosis as disruption in microbial communities associated with disease or health disorders.

Clarification 3: Instruction includes factors influencing the microbiome: diet, antibiotics, illness, stress, and lifestyle.

Clarification 4: Instruction includes interactions between the microbiome and human immune, endocrine, and nervous systems in maintaining health.

Clarification 5: Instruction includes evaluating evidence describing microbiome disruption and human health outcomes. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes examining historical developments related to microbiology, the human microbiome, and changing scientific understanding of microbial communities and health.

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Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

The Science of Nutrition

How food provides energy and materials for the human body; how nutritional inputs are processed and regulated; and how interactions between foods and biological systems support growth, balance, and life processes.

Grades 9-12

SC.912.NT.1 Explain how nutrients and calories in food provide chemical energy and raw materials for cellular processes; how the human body uses and regulates these substances; and how biochemical interactions support growth, repair, and maintenance.

SC.912.NT.1.1 Recall the characteristics of calories and nutrients found in food.

Benchmark Clarifications:

Clarification 1: Instruction includes calories as units of chemical energy from food, where 1 dietary Calorie equals 1 kilocalorie, and that this energy is used to fuel cellular processes.

Clarification 2: Instruction includes distinguishing energy content (calories) from materials used for growth, repair, and regulation (nutrient function).

Clarification 3: Instruction includes major nutrient categories: macronutrients, micronutrients, fiber, and water, and their general roles in the body.

Clarification 4: Instruction includes empty calories as sources of energy that contribute little to no essential nutrients.

SC.912.NT.1.2 Explain biochemical interactions between nutrients and the human body.

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Example: Case Study – A Florida Gulf Coast fishing cooperative analyzes snapper as a locally harvested food that contains fats commonly described as healthy fats, primarily unsaturated fatty acids. Food scientists note that these fats contribute to fatty acids used in cell membrane structure and metabolic processes in the human body.

Classroom Demonstration – During a classroom demonstration, fish oil placed in water separates into droplets, modeling how fats behave differently from water-soluble nutrients. This prompts discussion about how lipid structure affects digestion, transport, and cellular interaction.

Student Task(s) –

Identify the type of fats found in Gulf Coast snapper that are commonly referred to as healthy fats and describe their basic chemical characteristics.

Explain how the structure of these fats allows them to participate in cell membrane formation and energy regulation.

Use observations from the fish oil demonstration to explain why fats require specific biological mechanisms for transport and use in the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes macromolecules essential to life (carbohydrates, lipids, proteins, and nucleic acids) and their functional roles rather than structural memorization.

Clarification 2: Instruction includes small molecules such as amino acids, sugars, and fatty acids as building blocks and metabolic participants.

Clarification 3: Instruction includes conceptual links between nutrient chemistry and biological function, including chemical interactions that support metabolism, cellular structure, and regulation.

Clarification 4: Instruction includes that some nutrients and nutrient components cannot be synthesized by the human body and must be obtained through food sources.

Clarification 5: Instruction includes that food composition and level of processing can influence how nutrients are broken down, absorbed, and used by the body.

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Clarification 6: Instruction includes developing and using models to explain how molecular structure influences nutrient function in biological systems. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Instruction includes analyzing observations or demonstrations to explain how different types of nutrients interact with the body. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.NT.1.3 Analyze how nutrients influence body systems, cellular processes, and human performance.

Example: Examine Gulf Coast snapper, a Florida-specific food that contains unsaturated fatty acids commonly referred to as healthy fats. Using a conceptual model, explain how these fats contribute to adenosine triphosphate (ATP) production, cell membrane structure, and interactions among digestion, gut health, and inflammation. Using this model, describe how the absorption and use of these unsaturated fatty acids may differ across life stages due to changes in metabolism and system efficiency.

Benchmark Clarifications:

Clarification 1: Instruction includes metabolism as the integrated set of chemical reactions that release energy, build molecules, and maintain cellular balance and adenosine triphosphate (ATP) as the cell's immediate energy currency produced through cellular respiration using energy from food molecules.

Clarification 2: Instruction includes that nutrients supply both energy and raw materials for cellular and system-level processes.

Clarification 3: Instruction includes conceptual connections between nutrition and interacting digestive, circulatory, endocrine, immune, and microbiome systems that exchange materials, energy, signals, and feedback to maintain function and balance.

Clarification 4: Instruction includes essential and nonessential amino acids as an example of nutrient dependence and synthesis.

Clarification 5: Instruction includes differences in how liquid nutrients and dissolved substances are absorbed and transported compared to solid foods.

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Clarification 6: Instruction includes that nutrient needs and physiological responses may differ across life stages such as growth, adulthood, and aging due to changes in metabolism, tissue maintenance, and system efficiency.

Clarification 7: Instruction includes that differences in food structure and processing may influence how efficiently nutrients are used in cellular and system-level processes.

Clarification 8: Instruction includes developing, using, evaluating, and revising models to explain how nutrients affect cellular and system-level processes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 9: Instruction includes analyzing data or scenarios to identify relationships between nutrient intake, metabolism, and system function. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.NT.2 Explain how foods vary in processing level, how whole and processed foods can be identified and analyzed, and how food labels provide information about nutrient content.

SC.912.NT.2.1 Recall the defining characteristics of whole, processed, and ultra-processed foods.

Benchmark Clarifications:

Clarification 1: Instruction includes whole foods as foods that are unprocessed or minimally changed from their natural form, with no or minimal added ingredients.

Clarification 2: Instruction includes processed foods as foods altered through physical, chemical, or industrial processes that may change composition, structure, or preservation.

Clarification 3: Instruction includes ultra-processed foods as industrial formulations designed for convenience, shelf stability, or palatability and often containing ingredients not commonly used in home food preparation.

Clarification 4: Instruction includes food processing as a continuum from minimally processed to highly processed and ultra-processed foods.

Clarification 5: Instruction includes that whole foods typically contain naturally occurring combinations of nutrients, fiber, and water that influence digestion and nutrient availability.

SC.912.NT.2.2 Analyze foods using the NOVA food classification system.

Benchmark Clarifications:

Clarification 1: Instruction includes NOVA as one food-classification framework based on the extent and purpose of food processing.

Clarification 2: Instruction includes NOVA's four food groups independent of nutrient quantity or dietary recommendations.

Clarification 3: Instruction includes analyzing foods by type of processing, industrial formulation, and role of additives rather than calories or individual nutrients alone.

Clarification 4: Instruction includes recognizing that foods with similar nutrient profiles may differ significantly in processing level.

Clarification 5: Instruction includes organizing, categorizing, and interpreting food-processing data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes using models or classification systems to organize foods based on processing categories. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.NT.2.3 Analyze foods based on the United States Department of Agriculture (USDA) and Food and Drug Administration (FDA) definitions of food processing and formulation.

Example: Analyze foods using USDA and FDA definitions of food processing and formulation. Determine how foods vary in extent and purpose of processing, ingredient formulation, and structural integrity to conceptually align with the NOVA food-classification framework.

Benchmark Clarifications:

Clarification 1: Instruction includes levels of food processing based on physical, chemical, and industrial alteration of agricultural products.

Clarification 2: Instruction includes preservation, refinement, formulation, and ingredient modification.

Clarification 3: Instruction includes composition, formulation complexity, and added substances such as sugars, oils, emulsifiers, stabilizers, flavors, colors, and preservatives.

Clarification 4: Instruction includes comparative analysis of foods with similar nutrient profiles but differing processing levels, structural integrity, and formulation purposes.

Clarification 5: Instruction includes conceptual alignment between USDA and FDA processing terminology and the NOVA food-classification framework.

SC.912.NT.2.4 Determine differences between whole foods and processed foods.

Example: Analyze foods produced or harvested in Florida, such as avocados, peanuts, citrus products, and Gulf Coast fish, to compare nutrient density, fiber content, ingredient complexity, food structure, and degree of processing.

Benchmark Clarifications:

Clarification 1: Instruction includes comparing whole and processed foods based on nutrient density, fiber content, ingredient complexity, and degree of structural alteration.

Clarification 2: Instruction includes analyzing how processing influences food composition, digestion, nutrient availability, and food structure.

Clarification 3: Instruction includes that foods with similar nutrient content may differ substantially in processing level.

Clarification 4: Instruction includes using real-world examples to support evidence-based comparisons.

SC.912.NT.2.5 Interpret nutrition panels and ingredient lists on packaged foods and beverages.

Benchmark Clarifications:

Clarification 1: Instruction includes identifying serving size, nutrient content, and ingredient composition.

Clarification 2: Instruction includes identifying added sugars listed under multiple names and locations within ingredient lists.

Clarification 3: Instruction includes identifying stimulant compounds such as caffeine within ingredient panels.

Clarification 4: Instruction includes evaluating how serving size and packaging may influence perceived nutrient content.

Clarification 5: Instruction includes analyzing quantitative label data such as serving size, nutrient amounts, and ingredient patterns. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.NT.2.6 Compare foods using nutrition labels, ingredient lists, processing information, and production-practice labels.

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Example: Interpret nutrition panels and ingredient lists from whole and processed foods to compare nutrient density, ingredient composition, added ingredients, serving size, processing level, and production-practice labels.

Benchmark Clarifications:

Clarification 1: Instruction includes comparing nutrition panels from whole and processed foods to evaluate differences in added ingredients, nutrient concentration, and processing indicators.

Clarification 2: Instruction includes using label evidence to support claims about food composition rather than health outcomes.

Clarification 3: Instruction includes identifying and interpreting production-practice labels such as organic, non-GMO, free-range, pasture-raised, grass-fed and bioengineered as descriptions of agricultural and production practices rather than a measure of nutritional quality.

Clarification 4: Instruction includes comparing foods with similar nutrient profiles but differing ingredients and processing levels.

Clarification 5: Instruction includes using evidence from labels, ingredient lists, and processing classifications to support scientific conclusions about food composition and processing.

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SC.912.NT.3 Analyze how whole and processed foods interact with human biology, influence digestion and energy regulation, and affect short- and long-term biological outcomes.

SC.912.NT.3.1 Compare consumption of whole foods and processed foods in terms of cost and nutrient density.

Benchmark Clarifications:

Clarification 1: Instruction includes comparing nutrient density relative to cost, packaging, and degree of processing.

Clarification 2: Instruction includes analyzing how processing levels may influence nutrient concentration and food structure rather than price alone.

Clarification 3: Instruction includes real-world examples to support evidence-based comparison.

SC.912.NT.3.2 Explain the impact of whole grains versus refined carbohydrates on nutrient density and energy levels.

Benchmark Clarifications:

Clarification 1: Instruction includes differences in fiber content, nutrient retention, and structural integrity of whole grains versus refined carbohydrates.

Clarification 2: Instruction includes how digestion rate influences timing and stability of energy availability.

Clarification 3: Instruction includes carbohydrate structure conceptually without molecular diagrams.

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SC.912.NT.3.3 Describe short-term effects of processed food consumption on the human body.

Example: Analyze a short-term meal scenario involving processed foods to describe how low nutrient density and altered food structure influence gut health and digestion. Explain immediate digestive responses related to low fiber intake, including the effects on gastrointestinal activity and satiety compared to nutrient sufficiency. Additionally, describe any short-term physiological responses, such as rapid blood glucose availability from added sugars and osmotic or thirst responses linked to sodium content.

Benchmark Clarifications:

Clarification 1: Instruction includes rapid increases in available glucose in the bloodstream following intake of foods high in added sugars.

Clarification 2: Instruction includes osmotic and thirst responses associated with high sodium intake.

Clarification 3: Instruction includes the distinction between satiety and nutrient sufficiency.

Clarification 4: Instruction includes digestive responses related to low fiber intake and altered food structure.

Clarification 5: Instruction includes conceptual relationships among dietary fiber, food composition, and gut microbiome function.

SC.912.NT.3.4 Analyze research on the impact of processed food consumption on the human body.

Benchmark Clarifications:

Clarification 1: Instruction includes analysis of scientific studies, data trends, and population-level research findings related to processed food consumption.

Clarification 2: Instruction includes interpreting correlation versus causation, study design, and limitations of nutrition research.

Clarification 3: Instruction includes recognizing variability in study populations and outcomes.

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Clarification 4: Instruction includes conceptual understanding that food processing, handling, and preservation methods influence contamination risk and food stability.

Clarification 5: Instruction includes analyzing data trends, graphs, and study results to evaluate claims about food processing.

Clarification 6: Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 7: Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.NT.3.5 Explain the impact of frequent or repeated consumption over time of processed foods.

Benchmark Clarifications:

Clarification 1: Instruction includes explaining how repeated patterns of intake over time may influence energy regulation and metabolic efficiency.

Clarification 2: Instruction includes effects on the digestive, endocrine, and circulatory systems conceptually.

Clarification 3: Instruction includes cumulative biological effects rather than isolated events.

SC.912.NT.3.6 Explain how processed foods affect digestion and blood sugar levels.

Benchmark Clarifications:

Clarification 1: Instruction includes that refined carbohydrates typically digest more rapidly due to reduced structural complexity and fiber content.

Clarification 2: Instruction includes how rapid digestion may lead to short-term fluctuations in blood glucose levels.

Clarification 3: Instruction includes insulin response and insulin resistance conceptually, without molecular or clinical detail.

Clarification 4: Instruction includes glycemic index as a comparative measure of blood sugar response, not a dietary rule.

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SC.912.NT.4 Explain how different categories of beverages affect hydration, nutrient intake, and physiological regulation in the human body.

SC.912.NT.4.1 Analyze how water contributes to cellular hydration, circulation, and temperature regulation.

Benchmark Clarifications:

Clarification 1: Instruction includes water as the primary solvent and transport medium for nutrients, gases, and waste products in the human body.

Clarification 2: Instruction includes water's role in maintaining osmotic balance, blood volume, and cellular hydration.

Clarification 3: Instruction includes comparing beverages based on water content and dissolved substances rather than flavor or preference.

Clarification 4: Instruction includes how substances such as sugars, electrolytes, and caffeine may influence hydration status conceptually.

SC.912.NT.4.2 Compare the nutrient content, added sugars, and biological effects of beverages.

Benchmark Clarifications:

Clarification 1: Instruction includes beverages such as fruit juice, milk, soda, coffee, tea, and energy drinks.

Clarification 2: Instruction includes distinguishing naturally occurring sugars from added sugars and their different physiological contexts.

Clarification 3: Instruction includes conceptual analysis of protein, minerals, and fats in milk as contributors to nutrient intake.

Clarification 4: Instruction includes acids and added sugars in soda and their influence on digestion and hydration dynamics.

Clarification 5: Instruction includes caffeine and other stimulant compounds in energy drinks as biologically active substances.

Clarification 6: Instruction includes comparing short-term physiological responses such as hydration status, energy availability, and nervous system stimulation.

SC.912.NT.4.3 Explain how stimulant-containing beverages influence the nervous system, hydration status, and energy regulation.

Benchmark Clarifications:

Clarification 1: Instruction includes caffeine as a central nervous system stimulant that alters alertness and signaling pathways conceptually.

Clarification 2: Instruction includes context-dependent diuretic effects of caffeine and their potential influence on hydration status.

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Clarification 3: Instruction includes interactions between rapidly digestible sugars and stimulants, affecting short-term energy regulation.

Clarification 4: Instruction includes distinguishing stimulation from sustained energy availability.

SC.912.NT.4.4 Evaluate beverage marketing claims using hydration science and nutritional evidence.

Benchmark Clarifications:

Clarification 1: Instruction includes analyzing claims such as natural, hydrating, electrolyte, and energy using scientific definitions.

Clarification 2: Instruction includes cross-referencing marketing claims with ingredient lists, added sugars, stimulants, and nutrient data.

Clarification 3: Instruction includes identifying incomplete, exaggerated, or unsupported claims using evidence-based reasoning.

Clarification 4: Instruction includes recognizing the role of advertising techniques in shaping consumer perception.

Clarification 5: Instruction includes evaluating claims using data, label evidence, and scientific reasoning.

Clarification 6: Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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The Science of Fungi

How fungal cells build and support whole organisms, obtain and recycle energy and matter, grow and reproduce, interact with their environments, and shape the ecosystems on which life depends.

Proposed DRAFT Standards

Grades 9-12

SC.912.FG.1 Explain the unique structural organization of fungal cells, including fungal cell walls, the nucleus, and the nucleolus, and describe how these structures support growth, protection, genetic continuity, and cellular regulation.

SC.912.FG.1.1 Describe the structure and composition of fungal cell walls.

Benchmark Clarifications

Clarification 1: Instruction includes chitin as a major structural component of fungal cell walls.

Clarification 2: Instruction includes glucans and other polysaccharides that contribute to cell-wall structure.

Clarification 3: Instruction includes functions of fungal cell walls in support, protection, shape maintenance, and environmental interactions.

Clarification 4: Instruction includes comparisons among fungal cell walls, plant cell walls, and animal cells.

SC.912.FG.1.2 Identify the structural features of the nucleus and nucleolus in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the nuclear envelope as a double membrane structure with nuclear pores.

Clarification 2: Instruction includes nuclear components: chromatin and nucleolus.

Clarification 3: Instruction includes the nucleolus as a distinct non-membrane bound region within the nucleus.

Clarification 4: Instruction includes the role of nuclear pores in regulating the movement of ribonucleic acid (RNA) and proteins.

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SC.912.FG.1.3 Explain how the nucleus functions in storing genetic information and regulating cellular activity in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes the deoxyribonucleic acid (DNA) housed within the nucleus.

Clarification 2: Instruction includes the regulation of gene expression and control of cellular processes.

Clarification 3: Instruction includes coordination of metabolic activity, growth, and reproduction in fungal cells.

SC.912.FG.1.4 Explain the role of the nucleolus in ribosome production in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes ribosomal ribonucleic acid (RNA) in the nucleolus.

Clarification 2: Instruction includes the assembly of ribosomal subunits prior to export to the cytoplasm.

Clarification 3: Instruction includes ribosomes as essential for protein synthesis.

SC.912.FG.2 Explain how fungal body organization, including hyphae and mycelia, supports growth, transport, nutrient acquisition, and interactions with the environment.

SC.912.FG.2.1 Identify the structural features of fungal hyphae and mycelia.

Benchmark Clarifications:

Clarification 1: Instruction includes hyphae as long branching filamentous cells that form the fungal body.

Clarification 2: Instruction includes septate and coenocytic (non-septate) hyphae.

Clarification 3: Instruction includes mycelium as a network of interconnected hyphae.

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Clarification 4: Instruction includes relationships among hyphal structure, surface area, and environmental interactions.

SC.912.FG.2.2 Explain how hyphal organization supports nutrient absorption and fungal growth.

Benchmark Clarifications:

Clarification 1: Instruction includes secretion of digestive enzymes into surrounding substrates.

Clarification 2: Instruction includes extracellular digestion and nutrient absorption.

Clarification 3: Instruction includes mycelia as extensive absorptive networks.

Clarification 4: Instruction includes relationships among nutrient acquisition, growth, and ecological function.

SC.912.FG.2.3 Analyze how hyphae and mycelia function as integrated transport and absorptive systems.

Example: Use a light microscope to observe black bread mold (Rhizopus stolonifera), filamentous fungi commonly found in Florida's warm, humid environments. Based upon these observations, explain how cytoplasmic streaming and vesicle transport move nutrients, enzymes, and cellular components along hyphae to support hyphal tip growth. Connect intracellular transport to the ability of Rhizopus stolonifera to grow rapidly and spread in Florida conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes movement of nutrients, water, organelles, and signaling molecules throughout fungal networks.

Clarification 2: Instruction includes cytoplasmic continuity within fungal filaments.

Clarification 3: Instruction includes relationships between intracellular transport and hyphal growth.

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Clarification 4: Instruction includes defining fungal-system boundaries and analyzing interactions between fungi and their environments.

Clarification 5: Instruction includes constructing and interpreting systems models that explain interactions among hyphae, mycelia, nutrient acquisition, and growth. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.3 Explain how cytoplasm and intracellular transport support biochemical reactions, growth, communication, and movement of materials within fungal cells and hyphae.

SC.912.FG.3.1 Describe the structure and composition of cytoplasm in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes cytosol, organelles, and intracellular structures associated with fungal cytoplasm.

Clarification 2: Instruction includes cytoplasm as a medium supporting biochemical activity.

Clarification 3: Instruction includes continuity of cytoplasm throughout fungal hyphae.

SC.912.FG.3.2 Explain how cytoplasm supports organelle function and biochemical activity in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes cytoplasm as the site of metabolic and enzymatic reactions.

Clarification 2: Instruction includes support and spatial organization of organelles.

Clarification 3: Instruction includes diffusion and molecular interactions within the cytosol.

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SC.912.FG.3.3 Explain how cytoplasmic transport supports intracellular organization and communication in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes vesicle transport among organelles and cellular regions.

Clarification 2: Instruction includes intracellular movement of proteins, signaling molecules, and cellular materials.

Clarification 3: Instruction includes coordination of intracellular communication and cellular organization.

SC.912.FG.4 Explain how fungal organelles support metabolism, energy transformation, synthesis, transport, storage, detoxification, growth, and homeostasis.

SC.912.FG.4.1 Describe the structure and function of mitochondria in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes mitochondrial membranes and internal compartments.

Clarification 2: Instruction includes cellular respiration as the primary function of mitochondria.

Clarification 3: Instruction includes ATP production supporting fungal metabolism and growth.

SC.912.FG.4.2 Explain the roles of vacuoles in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes storage of water, nutrients, metabolites, and wastes.

Clarification 2: Instruction includes regulation of osmotic conditions and ion balance.

Clarification 3: Instruction includes turgor pressure and hyphal growth.

Clarification 4: Instruction includes maintenance of cellular homeostasis.

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SC.912.FG.4.3 Explain the roles of the endoplasmic reticulum, Golgi apparatus, and ribosomes in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes protein synthesis by ribosomes.

Clarification 2: Instruction includes protein and lipid synthesis by the endoplasmic reticulum.

Clarification 3: Instruction includes modification, sorting, and packaging of cellular products by the Golgi apparatus.

Clarification 4: Instruction includes secretion of enzymes associated with fungal growth and nutrient acquisition.

SC.912.FG.4.4 Explain the roles of peroxisomes and other metabolic organelles in fungal cells.

Benchmark Clarifications:

Clarification 1: Instruction includes fatty-acid metabolism.

Clarification 2: Instruction includes detoxification of metabolic byproducts including hydrogen peroxide.

Clarification 3: Instruction includes maintenance of cellular health during active metabolism.

Clarification 4: Instruction includes constructing explanations from evidence describing the role of metabolic organelles in fungal-cell function. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.4.5 Analyze interactions among fungal organelles that support metabolism and growth.

Benchmark Clarifications:

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Clarification 1: Instruction includes coordinated function among ribosomes, endoplasmic reticulum, Golgi apparatus, vesicles, vacuoles, mitochondria, and peroxisomes.

Clarification 2: Instruction includes movement of molecules through intracellular transport pathways.

Clarification 3: Instruction includes relationships among synthesis, transport, storage, respiration, and growth.

Clarification 4: Instruction includes constructing systems models that explain interactions among fungal organelles during metabolism, transport, and growth. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.5 Classify fungi into major groups, including chytrids, zygomycetes, glomeromycetes, ascomycetes, and basidiomycetes based on cellular structures, reproductive strategies, and ecological roles.

SC.912.FG.5.1 Identify and classify chytrids based on their distinctive cellular structures, reproductive strategies, and ecological roles.

Example: Case Study – In a Florida freshwater wetland, biologists observe declining frog populations with skin infections that disrupt respiration and water balance. Laboratory analysis reveals a fungus that produces flagellated waterborne spores and reproduces in moist environments, spreading through direct contact and contaminated water. Based on these motile spores, aquatic reproduction, and parasitic impact on frogs, the organism is classified as chytrid fungus (Chytridiomycosis) which is caused by the pathogen (Batrachochytrium dendrobatidis Bd).

Student Task(s) –

Cite at least three pieces of evidence from the case study.

Explain how the fungus' reproductive strategy supports its spread in Florida wetlands.

Describe how parasitism of frog skin affects frog survival.

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Benchmark Clarifications:

Clarification 1: Instruction includes the presence of flagellated spores as a defining characteristic of chytrids.

Clarification 2: Instruction includes sexual and asexual reproduction in aquatic or moist environments.

SC.912.FG.5.2 Classify zygomycetes based on structural features and reproductive strategies.

Benchmark Clarifications:

Clarification 1: Instruction includes the formation of zygospores during sexual reproduction.

Clarification 2: Instruction includes hyphal structure lacking septa.

Clarification 3: Instruction includes ecological roles such as decomposers of organic matter and their association with food spoilage.

SC.912.FG.5.3 Differentiate and classify glomeromycetes based on symbiotic relationships and cellular organization.

Example: Explore the mutualistic relationship between glomeromycete fungi and bald cypress trees (Taxodium distichum) in the Apalachicola National Forest in north Florida. Explain how arbuscular mycorrhizae formed within cypress roots increase water and phosphorus uptake for the tree, while the fungus receives sugars produced through photosynthesis. Classify the fungus as a glomeromycete using evidence from its symbiosis, cellular organization, and asexual reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes the formation of arbuscular mycorrhizae with plant roots.

Clarification 2: Instruction includes asexual reproduction as the primary reproductive strategy.

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Clarification 3: Instruction includes ecological roles in nutrient exchange and enhancement of plant growth.

SC.912.FG.5.4 Classify ascomycetes using reproductive structures and cellular features.

Example: Case Study – In Everglades National Park, the ruffle lichen (Parmotrema paresorediosum) grows on tree bark in the warm, humid habitats of south Florida. This lichen is a symbiotic partnership in which ascomycete fungus forms septate hyphae and reproductive structures that produce ascospores, while its photosynthetic partner supplies sugars through photosynthesis. The presence of the fungal ascus-based reproduction and its role in a lichen mutualism supports the fungal classification as an ascomycete.

Student Task(s) –

What evidence from the case study indicates that the fungal partner in the Florida lichen is an ascomycete?

How does the symbiotic relationship with the lichen benefit both the ascomycete fungus and its photosynthetic partner?

Benchmark Clarifications:

Clarification 1: Instruction includes ascus formation and production of ascospores.

Clarification 2: Instruction includes septate hyphae and varied fruiting body structures.

Clarification 3: Instruction includes ecological roles such as decomposition, symbiotic relationships, and pathogenic interactions.

Clarification 4: Instruction includes lichen formation as a symbiotic ecological strategy of some ascomycetes.

SC.912.FG.5.5 Classify basidiomycetes based on reproductive structures and ecological functions.

Benchmark Clarifications:

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Clarification 1: Instruction includes basidium formation and production of basidiospores.

Clarification 2: Instruction includes complex fruiting bodies such as mushrooms.

Clarification 3: Instruction includes ecological roles in decomposition, nutrient cycling, and symbiotic relationships.

SC.912.FG.5.6 Compare and justify the classification of major fungal groups using structural, reproductive, and ecological criteria.

Example: Use a dichotomous key to classify unknown fungal organisms into major groups based on structural features, reproductive strategies, and ecological roles. After determining classification, justify the decision by explaining how multiple characteristics work together as a system rather than relying on a single trait.

Benchmark Clarifications:

Clarification 1: Instruction includes using multiple characters rather than a single trait for classification.

Clarification 2: Instruction includes comparison charts, dichotomous keys, or classification matrices.

Clarification 3: Instruction includes patterns that distinguish fungal groups at a systems level.

Clarification 4: Instruction includes evaluating classification evidence using structural, reproductive, and ecological datasets. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.6 Describe the structures and functions of fungal reproductive organization, including fruiting bodies, reproductive structures, and spores; and explain how these components support reproduction, survival, and dispersal.

SC.912.FG.6.1 Identify the structures involved in fungal reproduction.

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Benchmark Clarifications:

Clarification 1: Instruction includes reproductive structures such as sporangia, conidiophores, asci, and basidia.

Clarification 2: Instruction includes the distinction between asexual and sexual reproductive structures.

Clarification 3: Instruction includes fruiting bodies as specialized structures that contain or support reproductive structures.

Clarification 4: Instruction includes that reproductive structures may be microscopic or macroscopic.

SC.912.FG.6.2 Explain the function of fruiting bodies in fungal reproduction and dispersal.

Example: Case Study – In a mixed hardwood forest in north Florida, students conducting an ecological survey noticed clusters of thin, fan-shaped fungi growing on fallen oak logs. The fungi are arranged in overlapping layers forming shelf-like structures along the surface of the decaying wood. The area is shaded by trees with high humidity and frequent rainfall. The species identified as Turkey Tail fungus (Trametes versicolor) is a common north Florida forest fungus that plays a major role in wood decomposition.

Student Task(s) –

Identify the structure responsible for reproduction in Trametes versicolor.

Explain how the shape and position of the fruiting bodies help increase spore dispersal in a forest environment.

Explain how environmental conditions in north Florida forests support fruiting body formation in this species.

Benchmark Clarifications:

Clarification 1: Instruction includes fruiting bodies as multicellular structures that elevate reproductive structures above the substrate.

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Clarification 2: Instruction includes increased efficiency of spore release and dispersal due to fruiting body structure.

Clarification 3: Instruction includes the relationship between environmental conditions and fruiting body formation.

Clarification 4: Instruction includes predicting how environmental conditions influence fruiting-body development and spore dispersal using models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.6.3 Explain the role of spores in fungal reproduction, survival, and dispersal.

Benchmark Clarifications:

Clarification 1: Instruction includes spores as reproductive units capable of developing into new fungi.

Clarification 2: Instruction includes spores produced through asexual or sexual processes.

Clarification 3: Instruction includes adaptations that allow spores to survive harsh environmental conditions.

Clarification 4: Instruction includes dispersal mechanisms: wind, water, and animal activity.

SC.912.FG.6.4 Explain how fungal structures work together to support survival and reproduction.

Example: Using observations of a Suillus species, a fungus commonly found in Florida pine flatwoods and associated with pine trees, make a claim about nutrient availability and how it affects fungal survival and reproduction. Support your claim with evidence related to the extent of mycelial growth and the presence or absence of fruiting bodies under different nutrient conditions. Use reasoning to explain how nutrient absorption by hyphae at the cellular level scales up to organism level reproductive success.

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Benchmark Clarifications:

Clarification 1: Instruction includes the integration of hyphae, mycelium, reproductive structures, and spores into a coordinated life cycle.

Clarification 2: Instruction includes the allocation of resources from the mycelium to fruiting bodies during reproduction.

Clarification 3: Instruction includes evaluating evidence linking nutrient acquisition, growth, and reproductive success. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.7 Explain how core fungal physiological processes, including extracellular digestion, cellular respiration, nutrient absorption, and growth regulation, enable fungal survival; and how these processes contribute to energy flow and drive matter cycling.

SC.912.FG.7.1 Analyze extracellular digestion in fungi and its role in attaining nutrients.

Benchmark Clarifications:

Clarification 1: Instruction includes enzyme secretion from fungal hyphae into the surrounding substrate.

Clarification 2: Instruction includes breakdown of complex organic molecules into simpler chemical components.

Clarification 3: Instruction includes extracellular digestion occurring outside the fungal cell prior to uptake.

Clarification 4: Instruction includes the utilization of organic substrates through extracellular biochemical processes.

SC.912.FG.7.2 Trace nutrient uptake in fungi following extracellular digestion.

Benchmark Clarifications:

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Clarification 1: Instruction includes movement of small organic molecules across the fungal cell wall and cell membrane.

Clarification 2: Instruction includes diffusion and active transport as mechanisms of nutrient uptake.

Clarification 3: Instruction includes the relationship between nutrient uptake, metabolism, growth, and reproduction.

Clarification 4: Instruction includes calculating and interpreting surface-area-to-volume relationships associated with nutrient absorption efficiency. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.7.3 Evaluate the role of cellular respiration in fungal energy transformation and survival.

Benchmark Clarifications:

Clarification 1: Instruction includes cellular respiration as a pathway for chemical energy conversion.

Clarification 2: Instruction includes aerobic respiration with mitochondria and anaerobic pathways under limited oxygen conditions.

Clarification 3: Instruction includes adenosine triphosphate (ATP) as the primary energy carrier in fungal cells.

Clarification 4: Instruction includes the energy requirements for biosynthesis, transport, growth, and cellular maintenance.

Clarification 5: Instruction includes comparing energy production in aerobic and anaerobic pathways using quantitative data. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.7.4 Explain how regulation of fungal growth supports survival in changing environments.

Benchmark Clarifications:

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Clarification 1: Instruction includes hyphal extension and branching patterns in response to nutrient availability.

Clarification 2: Instruction includes the coordination of cell wall synthesis, cytoplasmic flow, and vesicle transport.

Clarification 3: Instruction includes environmental factors: moisture, temperature, and substrate composition.

Clarification 4: Instruction includes efficient substrate colonization and competitive resource use.

Clarification 5: Instruction includes using growth models to predict fungal responses to environmental changes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.7.5 Analyze fungi as integrated biological systems.

Example: Investigate baker's yeast (Saccharomyces cerevisiae) by conducting a fermentation and respiration lab in which yeast is grown under different nutrient or oxygen conditions and carbon dioxide production is measured by gas collection or balloon inflation. Using the results, explain how mitochondria and other metabolic organelles coordinate energy transformation, biosynthesis, and recycling to meet cellular demands. Connect differences in carbon dioxide (〖CO〗_2) production to how energy use at the cellular level scales up to support overall fungal growth and survival.

Benchmark Clarifications:

Clarification 1: Instruction includes interactions among hyphae, mycelia, vacuoles, metabolic organelles, and reproductive structures.

Clarification 2: Instruction includes relationships among extracellular digestion, nutrient absorption, cellular respiration, growth, and reproduction.

Clarification 3: Instruction includes movement of matter and transformation of energy through fungal systems.

Clarification 4: Instruction includes relationships between environmental conditions and fungal physiological responses.

Clarification 5: Instruction includes constructing and interpreting systems models that explain how cellular and organismal processes function together to support fungal survival and reproduction. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.8 Explain how fungi reproduce through both asexual and sexual strategies, including spore formation; and analyze the advantages and disadvantages of each method for survival, dispersal, and genetic diversity.

SC.912.FG.8.1 Differentiate asexual and sexual reproduction in fungi.

Benchmark Clarifications:

Clarification 1: Instruction includes asexual reproductive mechanisms: mitotic spore formation and budding.

Clarification 2: Instruction includes sexual reproductive mechanisms: plasmogamy, karyogamy, and meiosis.

Clarification 3: Instruction includes genetic similarity in asexual reproduction and genetic variation in sexual reproduction.

Clarification 4: Instruction includes spore dispersal potential associated with each reproductive strategy.

SC.912.FG.8.2 Analyze the advantages and disadvantages of fungal reproductive strategies.

Benchmark Clarifications:

Clarification 1: Instruction includes rapid population increase and colonization associated with asexual reproduction.

Clarification 2: Instruction includes genetic diversity and environmental adaptability associated with sexual reproduction.

Clarification 3: Instruction includes the trade-offs related to energy investment, time, and environmental conditions.

Clarification 4: Instruction includes survival across short-term and long-term environmental change.

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Clarification 5: Instruction includes analyzing environmental and population data to determine advantages of reproductive strategies. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.8.3 Explain how environmental conditions influence fungal reproductive strategies.

Benchmark Clarifications:

Clarification 1: Instruction includes nutrient availability and substrate conditions.

Clarification 2: Instruction includes moisture, temperature, and oxygen availability.

Clarification 3: Instruction includes stress-induced shifts between asexual and sexual reproduction.

Clarification 4: Instruction includes predicting reproductive responses to changing environmental conditions using models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.9 Explain how fungi interact with their environment and other organisms, including their ecological roles, adaptations, symbiotic relationships, and responses to biotic and abiotic stressors.

SC.912.FG.9.1 Explain the ecological roles of fungi within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes ecological roles: decomposers, mutualists, and pathogens.

Clarification 2: Instruction includes contributions to nutrient availability and energy transfer.

Clarification 3: Instruction includes fungi interactions with plants, animals, and microorganisms.

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Clarification 4: Instruction includes fungi as regulators of population dynamics and community structure.

Clarification 5: Instruction includes evaluating ecological evidence describing fungal roles in ecosystem stability and nutrient availability. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.9.2 Explain fungal responses to biotic and abiotic environmental stressors.

Benchmark Clarifications:

Clarification 1: Instruction includes abiotic factors: temperature, moisture, pH, and substrate availability.

Clarification 2: Instruction includes biotic pressures: competition, predation, and host defenses.

Clarification 3: Instruction includes the structural, physiological, and life cycle adaptations supporting survival.

Clarification 4: Instruction includes short-term physiological responses and long-term adaptive responses.

Clarification 5: Instruction includes interpreting environmental datasets to evaluate fungal responses to biotic and abiotic stressors. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.10 Explain how fungi drive decomposition and nutrient cycling by breaking down organic matter, recycling essential elements, and supporting ecosystem productivity, stability, and resilience.

SC.912.FG.10.1 Explain the role of fungi in decomposition of organic matter.

Benchmark Clarifications:

Clarification 1: Instruction includes extracellular enzymatic breakdown of complex organic compounds.

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Clarification 2: Instruction includes decomposition of plant and animal biomass including cellulose and lignin.

Clarification 3: Instruction includes the conversion of organic matter into simpler chemical forms.

Clarification 4: Instruction includes enzymatic specialization enabling decomposition of resistant compounds.

SC.912.FG.10.2 Explain fungal contributions to carbon, nitrogen, and phosphorus cycling through decomposition and nutrient release.

Example: Model a north Florida forest ecosystem to show how fungal extracellular digestion of leaf litter supports nutrient recycling, fungal respiration, and biomass production, resulting in the return of carbon, nitrogen, and minerals to the soil and their availability to other living organisms.

Benchmark Clarifications:

Clarification 1: Instruction includes carbon release through respiration and organic matter breakdown.

Clarification 2: Instruction includes nitrogen transformation through decomposition of organic nitrogen compounds.

Clarification 3: Instruction includes phosphorus solubilization and release from organic materials.

Clarification 4: Instruction includes tracing movement of carbon, nitrogen, and phosphorus through ecosystem models and nutrient-cycle diagrams. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.10.3 Explain fungal contributions to nutrient transfer through symbiotic relationships.

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Example: Examine the symbiotic relationship between mycorrhizal fungi and saw palmetto (Serenoa repens), a dominant plant species in central Florida scrub and flatwoods ecosystems. Using diagrams or case studies, explain how mycorrhizae improve saw palmetto access to phosphorus and water in sandy Florida soils, how sugars produced through photosynthesis are transferred to the fungi, and how this mutualism increases nutrient retention and stability in central Florida ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes mycorrhizal nutrient exchange between fungi and plants.

Clarification 2: Instruction includes enhanced plant access to mineral nutrients and water.

Clarification 3: Instruction includes transfer of photosynthetically derived carbon to fungi.

Clarification 4: Instruction includes increased ecosystem nutrient retention through fungal symbiosis.

Clarification 5: Instruction includes evaluating evidence to describe the impacts of mycorrhizal interactions on nutrient availability, nutrient transfer, and plant productivity. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.10.4 Analyze how fungal decomposition and nutrient cycling influence ecosystem productivity, stability, and resilience.

Benchmark Clarifications:

Clarification 1: Instruction includes nutrient availability supporting primary production.

Clarification 2: Instruction includes regulation of organic matter accumulation.

Clarification 3: Instruction includes long-term maintenance of soil and ecosystem function.

Clarification 4: Instruction includes relationships among decomposition rates, nutrient cycling, ecosystem productivity, and resilience.

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Clarification 5: Instruction includes analyzing decomposition, nutrient-cycling, and ecosystem-recovery data to evaluate ecosystem responses to environmental change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and interpreting ecosystem models that trace the movement of matter among fungi, organisms, soils, and the environment and define system boundaries. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.11 Explain how fungal structural, physiological, reproductive, and ecological adaptations enable survival, growth, and reproduction across diverse environments and long-term environmental changes.

SC.912.FG.11.1 Explain the structural and physiological adaptations supporting fungal survival.

Benchmark Clarifications:

Clarification 1: Instruction includes hyphal structure and surface area optimization.

Clarification 2: Instruction includes metabolic flexibility and tolerance to environmental extremes.

Clarification 3: Instruction includes protective structures: spores and cell walls.

SC.912.FG.11.2 Explain reproductive and ecological adaptations supporting long-term persistence.

Example: Lab Description: Students culture baker's yeast (Saccharomyces cerevisiae), a non-pathogenic fungus, under different simulated Florida environmental conditions: high moisture, low moisture, and disturbance (simulated storm or flood condition using physical agitation or substrate change). Over several days, students record evidence of reproductive output, such as colony spread, budding rate, and spore visibility, as well as dispersal potential.

Benchmark Clarifications:

Clarification 1: Instruction includes reproductive strategy differences across environmental conditions.

Clarification 2: Instruction includes dispersal mechanisms enabling colonization of new habitats.

Clarification 3: Instruction includes adaptation across temporal environmental change.

SC.912.FG.11.3 Explain how fungal diversity contributes to ecosystem stability under environmental change.

Benchmark Clarifications:

Clarification 1: Instruction includes functional diversity among fungal species.

Clarification 2: Instruction includes redundancy in ecosystem processes.

Clarification 3: Instruction includes adaptation to long-term climate variability.

SC.912.FG.12 Explain how fungi initiate, influence, and respond to ecological succession, including their roles in soil formation, decomposition following disturbance, and ecosystem recovery over time.

SC.912.FG.12.1 Explain fungal roles during early and late stages of ecological succession.

Benchmark Clarifications:

Clarification 1: Instruction includes colonization of disturbed or newly formed substrates.

Clarification 2: Instruction includes decomposition and soil organic matter accumulation.

Clarification 3: Instruction includes facilitation of plant establishment and succession.

Clarification 4: Instruction includes temporal scales of succession and recovery.

Clarification 5: Instruction includes using succession models to predict fungal community changes through time. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.FG.12.2 Explain fungal contributions to ecosystem recovery following disturbance.

Benchmark Clarifications:

Clarification 1: Instruction includes the decomposition of dead biomass following disturbance events.

Clarification 2: Instruction includes nutrient release supporting regrowth.

Clarification 3: Instruction includes long-term soil development and ecosystem resilience.

Clarification 4: Instruction includes temporal scales of succession and recovery.

Clarification 5: Instruction includes evaluating evidence describing fungal contributions to ecosystem recovery. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.13 Explain how fungal populations grow, persist, and change over time by examining reproduction, dispersal, limiting factors, species interactions, carrying capacity, and ecological models that describe population and community dynamics.

SC.912.FG.13.1 Explain factors regulating fungal population growth and persistence.

Benchmark Clarifications:

Clarification 1: Instruction includes reproductive rates and dispersal capacity.

Clarification 2: Instruction includes limiting factors: nutrients, space, and environmental conditions.

Clarification 3: Instruction includes the carrying capacity within ecosystems.

Clarification 4: Instruction includes interpreting population-growth graphs and carrying-capacity models. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.13.2 Explain fungal population dynamics using ecological models.

Benchmark Clarifications:

Clarification 1: Instruction includes exponential and logistic growth patterns.

Clarification 2: Instruction includes species interactions affecting population size.

Clarification 3: Instruction includes community-level consequences of population change.

Clarification 4: Instruction includes comparing ecological model predictions with observed fungal population data. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.14 Explain how invasive fungal species spread, disrupt ecosystems, alter ecological processes, and impact native species; and evaluate the human activities and management strategies associated with their introduction and control.

SC.912.FG.14.1 Explain mechanisms of invasive fungal spread and establishment.

Benchmark Clarifications:

Clarification 1: Instruction includes human-mediated transport pathways.

Clarification 2: Instruction includes high reproductive output and dispersal efficiency.

Clarification 3: Instruction includes the absence of natural predators or competitors.

SC.912.FG.14.2 Evaluate ecological and management consequences of invasive fungi.

Benchmark Clarifications:

Clarification 1: Instruction includes the reduction of native species populations.

Clarification 2: Instruction includes the alteration of ecosystem processes.

Clarification 3: Instruction includes management strategies: prevention and control.

Clarification 4: Instruction includes using ecological models to predict ecosystem impacts of invasive fungi and management actions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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Clarification 5: Instruction includes evaluating strengths and limitations of management strategies using scientific evidence. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.15 Explain how anthropogenic activities affect fungi by altering habitats, changing land and water use, introducing pollution, influencing climate-related environmental conditions, and protecting fungal diversity through conservation and management efforts.

SC.912.FG.15.1 Explain the anthropogenic impacts on fungal habitats and environmental conditions.

Benchmark Clarifications:

Clarification 1: Instruction includes land-use change and habitat fragmentation.

Clarification 2: Instruction includes pollution and chemical inputs.

Clarification 3: Instruction includes changes in precipitation and temperature patterns.

Clarification 4: Instruction includes analyzing environmental and land-use data to evaluate anthropogenic impacts on fungi. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.15.2 Explain conservation and management strategies supporting fungal diversity.

Benchmark Clarifications:

Clarification 1: Instruction includes habitat protection and restoration.

Clarification 2: Instruction includes sustainable land-use practices.

Clarification 3: Instruction includes biodiversity monitoring and conservation planning.

Clarification 4: Instruction includes evaluating conservation models and biodiversity datasets. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.FG.16 Explain how fungi sustain natural and human systems by supporting plant productivity, recycling nutrients, forming symbiotic relationships, producing food and medicinal compounds, and contributing to ecosystem services essential for life on Earth.

SC.912.FG.16.1 Explain fungal contributions to ecosystem services and plant productivity.

Benchmark Clarifications:

Clarification 1: Instruction includes mycorrhizal enhancement of plant growth.

Clarification 2: Instruction includes nutrient recycling and soil health.

Clarification 3: Instruction includes maintenance of ecosystem stability.

Clarification 4: Instruction includes fungi as foundational components of ecosystem service networks.

Clarification 5: Instruction includes evaluating evidence describing fungal contributions to ecosystem services and productivity. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.FG.16.2 Explain fungal importance to human systems and sustainability.

Benchmark Clarifications:

Clarification 1: Instruction includes food production and fermentation.

Clarification 2: Instruction includes medicinal and industrial compound production.

Clarification 3: Instruction includes ecosystem services supporting life-support systems.

Clarification 4: Instruction includes evaluating scientific and societal evidence describing fungal contributions to medicine, food systems, and sustainability.

Clarification 5: Instruction includes examining historical discoveries, technological advances, and scientific contributions that led to the use of fungi in medicine, food production, biotechnology, and sustainability. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

The Science of Microorganisms

How microscopic life is structured, how it functions, how it interacts with living systems, and how microorganisms shape ecosystems, human health, and life on Earth.

Grades 9-12

SC.912.MO.1 Analyze how microorganisms are classified into major groups based on cellular structure, genetic organization, and modes of reproduction; and how these groups differ from one another and from multicellular life.

SC.912.MO.1.1 Identify and categorize major groups of microorganisms using shared biological characteristics.

Benchmark Clarifications:

Clarification 1: Instruction includes groups of microorganisms: bacteria, archaea, protists, fungi, and viruses.

Clarification 2: Instruction includes cellular organization: prokaryotic and eukaryotic cell types.

Clarification 3: Instruction includes genetic material organization and location.

Clarification 4: Instruction includes viruses as acellular entities distinct from cellular life.

Clarification 5: Instruction includes examining historical models, technological advances, and scientific developments that contributed to the classification of microorganisms and the distinction between cellular and acellular life. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.1.2 Differentiate major groups of microorganisms based on cellular structure.

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Example: Use light microscopes to observe prepared slides of bacterial cells, yeast (fungi), protists, and human cheek cells and record observable structural features such as nucleus presence, cell size, and level of organization. Compare how unicellular microorganisms perform all life functions within a single cell, while multicellular organisms rely on specialized cells working together. Summarize these findings by differentiating microbial cellular structure from multicellular cellular organization.

Benchmark Clarifications:

Clarification 1: Instruction includes the absence or presence of a nucleus and membrane-bound organelles.

Clarification 2: Instruction includes the characteristics of prokaryotic cells in bacteria and archaea.

Clarification 3: Instruction includes the characteristics of eukaryotic cells in protists and fungi.

SC.912.MO.1.3 Compare genetic organization among major groups of microorganisms.

Benchmark Clarifications:

Clarification 1: Instruction includes circular deoxyribonucleic acid (DNA) in prokaryotes and linear chromosomes in eukaryotic microorganisms.

Clarification 2: Instruction includes genome size and structural complexity across microbial groups.

Clarification 3: Instruction includes viral genetic material and reliance on host cellular machinery.

Clarification 4: Instruction includes the relationships between genetic organization and biological function.

Clarification 5: Instruction includes constructing and interpreting models that compare genome organization among major microbial groups and relate genetic organization to biological function.

Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.MO.1.4 Distinguish modes of reproduction among major groups of microorganisms.

Benchmark Clarifications:

Clarification 1: Instruction includes asexual reproduction: binary fission and mitosis.

Clarification 2: Instruction includes sexual reproduction in some protists and fungi.

Clarification 3: Instruction includes viral replication through host cell processes.

Clarification 4: Instruction includes reproductive strategies and population variability.

SC.912.MO.1.5 Evaluate the differences between microorganisms and multicellular organisms in organization and life processes.

Example: Examine microorganisms from a Florida freshwater wetland and compare them to a prepared slide of human skeletal muscle tissue to evaluate the differences between unicellular and multicellular organization. Observations should emphasize how microorganisms perform all life functions within a single cell while multicellular organisms rely on specialized cells, tissues, and organs. Use these observations to determine the advantages and limitations of microscopic life forms, such as efficiency and rapid reproduction versus reduced specialization and size-based constraints.

Benchmark Clarifications:

Clarification 1: Instruction includes unicellular, multicellular, and acellular organization.

Clarification 2: Instruction includes the specialization of cells, tissues, and organs in multicellular organisms.

Clarification 3: Instruction includes performance of life functions at the cellular level in microorganisms.

Clarification 4: Instruction includes limitations and advantages of microscopic life forms.

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Clarification 5: Instruction includes evaluating observational evidence comparing unicellular, multicellular, and acellular organization through laboratory investigations. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.2 Explain the structures and functions of prokaryotic cells and how these structures support microbial survival, growth, and reproduction.

SC.912.MO.2.1 Identify the major structural components of prokaryotic cells.

Benchmark Clarifications:

Clarification 1: Instruction includes cell structures of prokaryotes: cell membrane, cell wall, cytoplasm, ribosomes, nucleoid region, and plasmids.

Clarification 2: Instruction includes the external structures of prokaryotes: capsules, flagella, and pili when present.

Clarification 3: Instruction includes the absence of a nucleus and membrane-bound organelles.

Clarification 4: Instruction includes the representation of typical bacterial and archaeal cell structure.

SC.912.MO.2.2 Explain how prokaryotic cell structures support basic life functions.

Benchmark Clarifications:

Clarification 1: Instruction includes the cell membrane and regulation of materials entering and leaving the cell.

Clarification 2: Instruction includes ribosomes and protein synthesis.

Clarification 3: Instruction includes the nucleoid region and genetic information storage.

Clarification 4: Instruction includes the cell wall and structural support and protection.

SC.912.MO.2.3 Analyze how structural features of prokaryotic cells support survival in diverse environments.

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Benchmark Clarifications:

Clarification 1: Instruction includes capsules and protection from environmental stress and host defenses.

Clarification 2: Instruction includes flagella and movement toward favorable conditions.

Clarification 3: Instruction includes pili and attachment to surfaces and other cells.

Clarification 4: Instruction includes adaptations supporting survival in extreme conditions: high temperature, salinity, or acidity.

Clarification 5: Instruction includes predicting how structural adaptations support microbial survival under different environmental conditions using models. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.2.4 Explain how prokaryotic cell structure supports growth and reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes binary fission as the primary mode of reproduction.

Clarification 2: Instruction includes the role of deoxyribonucleic acid (DNA) replication prior to cell division.

Clarification 3: Instruction includes plasmids and genetic variation.

Clarification 4: Instruction includes small cell size and rapid population growth.

Clarification 5: Instruction includes interpreting population-growth data and quantitative models resulting from binary fission. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.2.5 Evaluate how prokaryotic cellular organization differs from eukaryotic cells in efficiency, specialization, and scale.

Benchmark Clarifications:

Clarification 1: Instruction includes unicellular organization and performance of all life processes within a single cell.

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Clarification 2: Instruction includes the lack of internal compartmentalization.

Clarification 3: Instruction includes advantages such as metabolic efficiency and rapid reproduction.

Clarification 4: Instruction includes limitations related to the lack of cellular specialization.

SC.912.MO.3 Explain how microorganisms obtain and use energy and matter through diverse metabolic pathways and how these processes support survival in a wide range of environments.

SC.912.MO.3.1 Differentiate major metabolic strategies used by microorganisms to obtain energy and matter.

Example: Analyze information cards that describe different microorganisms such as cyanobacteria, sulfur-oxidizing bacteria, yeast, and photosynthetic bacteria and classify each organism as photoautotroph, chemoautotroph, photoheterotroph, or chemoheterotroph. For each classification, identify the organism's energy source (light or chemical compound) and matter source (carbon dioxide, organic compounds, or inorganic substances).

Example: Create a two-axis classification chart (energy source x matter source) and place each microorganism in the current category, then write a brief explanation differentiating autotrophic versus heterotrophic strategies and how access to different energy and matter sources supports microbial survival in varied environments.

Benchmark Clarifications:

Clarification 1: Instruction includes autotrophic and heterotrophic metabolic strategies.

Clarification 2: Instruction includes photoautotrophs, chemoautotrophs, photoheterotrophs, and chemoheterotrophs.

Clarification 3: Instruction includes sources of energy: light and chemical compounds.

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Clarification 4: Instruction includes sources of matter: carbon dioxide, organic compounds, and inorganic substances.

Clarification 5: Instruction includes constructing and using classification models that relate energy sources and matter sources to microbial lifestyles. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.3.2 Explain how microorganisms use metabolic pathways to transform energy and matter for cellular function.

Benchmark Clarifications:

Clarification 1: Instruction includes cellular respiration and fermentation as energy-releasing pathways.

Clarification 2: Instruction includes aerobic and anaerobic metabolic processes.

Clarification 3: Instruction includes synthesis of biomolecules: proteins, lipids, and nucleic acids.

Clarification 4: Instruction includes transformation and conservation of matter during metabolic reactions.

SC.912.MO.3.3 Analyze how metabolic flexibility supports microbial survival in diverse environments.

Benchmark Clarifications:

Clarification 1: Instruction includes microorganisms in environments with limited oxygen, light, or nutrients.

Clarification 2: Instruction includes metabolic shifts between aerobic and anaerobic pathways.

Clarification 3: Instruction includes extremophiles in high temperature, salinity, acidity, or pressure environments.

Clarification 4: Instruction includes relationships between environmental conditions and metabolic pathway use.

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Clarification 5: Instruction includes evaluating environmental datasets that demonstrate metabolic flexibility and relationships between environmental conditions and microbial metabolic pathways. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.3.4 Explain how microbial metabolism contributes to population growth and ecological success.

Benchmark Clarifications:

Clarification 1: Instruction includes energy availability and biomass production.

Clarification 2: Instruction includes rapid reproduction supported by efficient metabolic processes.

Clarification 3: Instruction includes nutrient acquisition and recycling.

Clarification 4: Instruction includes metabolic efficiency at the cellular level.

SC.912.MO.3.5 Evaluate the advantages and limitations of different microbial metabolic pathways for survival and ecosystem functioning.

Benchmark Clarifications:

Clarification 1: Instruction includes the advantages: efficiency, adaptability, and rapid energy acquisition.

Clarification 2: Instruction includes the limitations: dependence on environmental conditions or energy sources.

Clarification 3: Instruction includes the trade-offs between energy yield and environmental accessibility.

Clarification 4: Instruction includes the connections between microbial metabolism and ecosystem processes such as nutrient cycling.

Clarification 5: Instruction includes comparing quantitative evidence describing energetic trade-offs among metabolic pathways and evaluating relationships among energy yield, efficiency, and environmental accessibility. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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Proposed DRAFT Standards

SC.912.MO.4 Analyze how microorganisms grow, reproduce, and exchange genetic information; and how these processes contribute to rapid population change.

SC.912.MO.4.1 Explain how microorganisms increase biomass and prepare for reproduction.

Benchmark Clarifications:

Clarification 1: Instruction includes cellular growth through assimilation of energy and matter.

Clarification 2: Instruction includes nutrient availability, environmental conditions, and resource limitations.

Clarification 3: Instruction includes growth at the cellular level prior to reproduction.

Clarification 4: Instruction includes relationships between growth rate and factors including temperature, moisture, and pH.

SC.912.MO.4.2 Differentiate modes of microbial reproduction and their effects on population size.

Example: Compare binary fission in prokaryotes and mitotic reproduction in eukaryotic microorganisms by modeling how population size changes over time under favorable conditions. Given initial population data and generation times, calculate population size across multiple reproduction cycles and represent the results using tables, graphs, and exponential expressions.

Benchmark Clarifications:

Clarification 1: Instruction includes asexual reproduction: binary fission in prokaryotes.

Clarification 2: Instruction includes mitotic reproduction in some eukaryotic microorganisms.

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Clarification 3: Instruction includes short generation times.

Clarification 4: Instruction includes exponential population increase under favorable conditions.

Clarification 5: Instruction includes interpreting tables, graphs, and mathematical models describing microbial population growth and population change over time. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.4.3 Analyze mechanisms of genetic information exchange among microorganisms.

Benchmark Clarifications:

Clarification 1: Instruction includes horizontal gene transfer mechanisms: transformation, transduction, and conjugation.

Clarification 2: Instruction includes plasmids and mobile genetic elements.

Clarification 3: Instruction includes genetic variation without sexual reproduction.

Clarification 4: Instruction includes genetic exchange within and across microbial populations.

Clarification 5: Instruction includes examining historical developments related to the mechanisms of genetic information exchange among microorganisms and how that understanding has changed as new observations, technologies, and scientific evidence became available. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.4.4 Explain how genetic exchange enhances microbial adaptability and population change.

Benchmark Clarifications:

Clarification 1: Instruction includes acquisition of traits: antibiotic resistance and novel metabolic capabilities.

Clarification 2: Instruction includes rapid spread of advantageous traits through populations.

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Clarification 3: Instruction includes links between genetic variation and survival in changing environments.

Clarification 4: Instruction includes implications for human health, ecosystems, and biotechnology.

SC.912.MO.4.5 Evaluate how growth, reproduction, and genetic exchange interact to shape microbial population dynamics.

Example: Analyze a case study of microbial communities in Florida citrus grove soils, where microorganisms support nutrient cycling and plant growth. Use population data or models to evaluate how rapid growth, asexual reproduction, and genetic exchange allow soil microbes to adapt to changing conditions such as moisture, nutrient availability, and seasonal management, while also considering resource limits and carrying capacity that regulate long-term population stability.

Benchmark Clarifications:

Clarification 1: Instruction includes combined effects of rapid growth, asexual reproduction, and genetic exchange.

Clarification 2: Instruction includes population responses to environmental change and selective pressure.

Clarification 3: Instruction includes advantages of rapid population change.

Clarification 4: Instruction includes constraints: resource depletion and environmental limits.

Clarification 5: Instruction includes logistic and exponential population-growth models.

Clarification 6: Instruction includes comparing model predictions with observed microbial population data.

Clarification 7: Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.MO.5 Analyze the structure of viruses; how they depend on host cells for replication; and how viral interactions affect organisms, populations, and ecosystems.

SC.912.MO.5.1 Identify the structural components of viruses and how they differ from cellular life.

Benchmark Clarifications:

Clarification 1: Instruction includes viral components: deoxyribonucleic acid (DNA) or ribonucleic acid (RNA), capsid, and envelope when present.

Clarification 2: Instruction includes viral genetic material as either single-stranded or double-stranded.

Clarification 3: Instruction includes absence of cellular structures: cytoplasm, ribosomes, and membrane-bound organelles.

Clarification 4: Instruction includes viruses as acellular entities distinct from prokaryotic and eukaryotic cells.

SC.912.MO.5.2 Explain how viruses rely on host cells to replicate and produce new viral particles.

Benchmark Clarifications:

Clarification 1: Instruction includes viral dependence on host cellular machinery for protein synthesis and genome replication.

Clarification 2: Instruction includes stages of viral replication cycles: attachment, entry, replication, assembly, and release.

Clarification 3: Instruction includes lytic and lysogenic replication strategies.

Clarification 4: Instruction includes host specificity based on receptor recognition.

Clarification 5: Instruction includes constructing and interpreting models that trace viral replication and host-cell interactions. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.5.3 Differentiate viral replication from cellular reproduction in microorganisms.

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Benchmark Clarifications:

Clarification 1: Instruction includes lack of independent metabolism or growth in viruses.

Clarification 2: Instruction includes comparison of viral replication with binary fission and mitosis.

Clarification 3: Instruction includes requirement of host infection for viral reproduction.

Clarification 4: Instruction includes implications of replication strategy for viral transmission and spread.

SC.912.MO.5.4 Analyze how viral infections affect individual organisms and population dynamics.

Example: Examine three case profiles representing an acute infection such as an influenza-like illness, a chronic infection such as a persistent viral infection, and a latent infection such as varicella-zoster virus which remains dormant in nerve cells after a person recovers from chickenpox and may reactivate years later as shingles. For each case, analyze how the infection pattern affects host cell function and survival, duration of infection, and likelihood of population-level spread.

Benchmark Clarifications:

Clarification 1: Instruction includes effects of viral infection on host cell function and survival.

Clarification 2: Instruction includes impacts on population size, immunity, and disease spread.

Clarification 3: Instruction includes viral roles in regulating population growth.

Clarification 4: Instruction includes interpreting infection-rate, transmission, and prevalence datasets to evaluate patterns of disease spread and population-level impacts of viral infections. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.5.5 Evaluate the roles of viruses in ecosystems and their influence on energy, matter, and population regulation.

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Benchmark Clarifications:

Clarification 1: Instruction includes viral roles in controlling microbial populations.

Clarification 2: Instruction includes contributions to nutrient cycling through cell lysis.

Clarification 3: Instruction includes viral influence on genetic diversity through gene transfer.

Clarification 4: Instruction includes viral presence in aquatic, terrestrial, and host-associated ecosystems.

Clarification 5: Instruction includes evaluating ecological evidence describing viral influences on microbial populations and nutrient cycling. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.6 Analyze the roles of microorganisms in ecosystems as primary producers, decomposers, symbionts, and regulators of population and nutrient dynamics.

SC.912.MO.6.1 Explain the role of microorganisms as primary producers in diverse ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes photosynthetic microorganisms: cyanobacteria and microalgae.

Clarification 2: Instruction includes conversion of light energy into chemical energy.

Clarification 3: Instruction includes carbon fixation as the base of aquatic and some terrestrial food webs.

Clarification 4: Instruction includes primary production in marine, freshwater, and soil ecosystems.

Clarification 5: Instruction includes phytoplankton as the dominant source of primary production in many marine ecosystems.

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SC.912.MO.6.2 Explain how microorganisms function as decomposers and recyclers of matter in ecosystems.

Example: Students are provided with data from a Florida mangrove ecosystem case study showing changes in mangrove leaf-litter mass and nutrient concentrations (carbon, nitrogen, and phosphorus) in soil or water over time. Using the data provided, explain how bacteria and fungi decompose mangrove detritus, increase nutrient availability for mangroves, algae, and other primary producers, and then create a labeled visual representation (diagram or flow model) that illustrates the movement of matter from detritus through decomposers to primary producers.

Benchmark Clarifications:

Clarification 1: Instruction includes bacteria and fungi involved in decomposition.

Clarification 2: Instruction includes breakdown of organic material from dead organisms and waste.

Clarification 3: Instruction includes release of nutrients: carbon, nitrogen, and phosphorus.

Clarification 4: Instruction includes nutrient availability for primary producers.

Clarification 5: Instruction includes interpreting decomposition and nutrient-cycling datasets to evaluate relationships among decomposition rates, nutrient availability, and ecosystem productivity. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.6.3 Analyze mutualistic, commensal, and parasitic relationships involving microorganisms.

Benchmark Clarifications:

Clarification 1: Instruction includes symbiotic relationships between microorganisms and plants, animals, or other microbes.

Clarification 2: Instruction includes mutualistic interactions such as nitrogen-fixing bacteria and plant roots.

Clarification 3: Instruction includes commensal and parasitic microbial relationships.

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Clarification 4: Instruction includes effects of symbiosis on survival and ecosystem stability.

SC.912.MO.6.4 Analyze how microorganisms regulate population size and community structure within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes microbial regulation of producer and consumer populations.

Clarification 2: Instruction includes pathogen-host interactions.

Clarification 3: Instruction includes population limitation through disease, competition, and predation.

Clarification 4: Instruction includes stabilization of ecosystem dynamics.

Clarification 5: Instruction includes constructing and interpreting ecological models of host-pathogen interactions and microbial regulation of populations. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.6.5 Evaluate the role of microorganisms in nutrient cycling and ecosystem homeostasis.

Benchmark Clarifications:

Clarification 1: Instruction includes microbial roles in carbon, nitrogen, phosphorus, and sulfur cycles.

Clarification 2: Instruction includes transformation of nutrients between organic and inorganic forms.

Clarification 3: Instruction includes regulation of nutrient availability and flow.

Clarification 4: Instruction includes connections between microbial activity and ecosystem balance.

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Clarification 5: Instruction includes constructing and interpreting systems models that connect nutrient cycles, microbial activity, and ecosystem function. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.7 Analyze how microorganisms drive the cycling of essential elements through ecosystems, including carbon, nitrogen, sulfur, and phosphorus.

SC.912.MO.7.1 Explain how microorganisms drive carbon cycling in ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes photosynthetic microorganisms contributing to carbon fixation.

Clarification 2: Instruction includes microbial respiration returning carbon dioxide to the atmosphere or aquatic systems.

Clarification 3: Instruction includes decomposition of organic carbon by bacteria and fungi.

Clarification 4: Instruction includes carbon movement among producers, consumers, decomposers, and the environment.

Clarification 5: Instruction includes marine primary productivity and carbon sequestration associated with phytoplankton and other photosynthetic microorganisms.

SC.912.MO.7.2 Explain the role of microorganisms in nitrogen cycling across ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes nitrogen fixation by bacteria and archaea.

Clarification 2: Instruction includes nitrification, denitrification, and ammonification by microorganisms.

Clarification 3: Instruction includes conversion of nitrogen between atmospheric, inorganic, and organic forms.

Clarification 4: Instruction includes nitrogen availability for plants and food webs.

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Clarification 5: Instruction includes constructing and interpreting ecosystem models that trace nitrogen through microbial transformations and ecosystem processes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.7.3 Explain how microorganisms contribute to sulfur cycling in ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes microbial transformations between sulfide, sulfate, and sulfur compounds.

Clarification 2: Instruction includes sulfur-oxidizing and sulfur-reducing microorganisms.

Clarification 3: Instruction includes sulfur cycling in aquatic, soil, and sediment environments.

Clarification 4: Instruction includes sulfur availability for biological processes.

SC.912.MO.7.4 Explain how microorganisms regulate phosphorus cycling and availability within ecosystems.

Benchmark Clarifications:

Clarification 1: Instruction includes microbial release of phosphorus during decomposition.

Clarification 2: Instruction includes phosphorus transformation between organic and inorganic forms.

Clarification 3: Instruction includes absence of a major atmospheric phosphorus component.

Clarification 4: Instruction includes phosphorus availability for primary production.

SC.912.MO.7.5 Evaluate how microbial nutrient cycling supports ecosystem productivity, stability, and resilience.

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Example: Analyze a case study focused on microbial nutrient cycling in the Guana Tolomato Matanzas (GTM) estuary in Northeast Florida, where bacteria and fungi in salt marsh sediments cycle carbon, nitrogen, phosphorus, and sulfur. Using provided nutrient and productivity data, evaluate how microbial activity supports marsh plant growth, food web stability, and ecosystem resilience. Explain how disruptions to microbial cycling can alter nutrient availability and balance in this estuarine ecosystem.

Benchmark Clarifications:

Clarification 1: Instruction includes connections between microbial activity and nutrient availability.

Clarification 2: Instruction includes interdependence of carbon, nitrogen, sulfur, and phosphorus cycles.

Clarification 3: Instruction includes ecosystem productivity and food web support.

Clarification 4: Instruction includes the impacts of disrupted microbial cycling on ecosystem balance.

Clarification 5: Instruction includes analyzing nutrient-cycle and ecosystem-productivity datasets to evaluate ecosystem productivity, stability, and resilience. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

Clarification 6: Instruction includes constructing and interpreting systems models that explain relationships among microbial nutrient cycling, ecosystem productivity, and ecosystem resilience. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.8 Analyze how microorganisms interact with the human body, including beneficial relationships, disease causation, and immune system interactions.

SC.912.MO.8.1 Describe beneficial interactions between microorganisms and the human body.

Example: Investigate real-world examples of mutualistic and commensal microorganisms that live on and within the human body, such as gut bacteria that help digest fiber, skin

microbes that limit pathogen growth, and mucosal microbes that support immune balance. Using short case examples such as gut bacteria producing vitamin K, skin microbes preventing infection, or intestinal microbes aiding nutrient absorption, describe how these microbial communities support digestion, nutrition, and internal balance.

Benchmark Clarifications:

Clarification 1: Instruction includes mutualistic and commensal microorganisms associated with the human body.

Clarification 2: Instruction includes microbial roles in digestion, nutrient absorption, and vitamin production.

Clarification 3: Instruction includes microbial communities on the skin, in the gut, and on mucosal surfaces.

Clarification 4: Instruction includes contributions to maintaining internal balance.

SC.912.MO.8.2 Explain how pathogenic microorganisms cause disease in humans.

Benchmark Clarifications:

Clarification 1: Instruction includes bacteria, viruses, fungi, and protists as disease-causing microorganisms.

Clarification 2: Instruction includes mechanisms such as tissue damage, toxin production, and disruption of normal body functions.

Clarification 3: Instruction includes routes of transmission including direct contact, airborne exposure, food, water, and vectors.

Clarification 4: Instruction includes variation in disease severity and outcomes among individuals.

SC.912.MO.8.3 Analyze interactions between microorganisms and the human immune system.

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Example: Examine a set of contrasting scenarios involving microorganisms interacting with the human body, including a harmless gut microbe, a short-term infection, and a more persistent microbial presence. Using diagrams, short readings, or case summaries, analyze how the immune system recognizes microorganisms, activates innate and adaptive responses, maintains tolerance to beneficial microbes, and uses immune signaling and regulation to manage infection.

Benchmark Clarifications:

Clarification 1: Instruction includes recognition of microorganisms by immune system components.

Clarification 2: Instruction includes innate and adaptive immune responses to microbial presence.

Clarification 3: Instruction includes tolerance of beneficial microorganisms.

Clarification 4: Instruction includes immune signaling and regulation during infection.

Clarification 5: Instruction includes examining historical developments related to the interactions between microorganisms and the human immune system and how understanding has changed as new observations, technologies, and scientific evidence became available. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.8.4 Differentiate beneficial, neutral, and harmful microbial interactions with the human body.

Example: Examine a set of real-world scenarios involving microorganisms interacting with the human body, such as gut bacteria aiding digestion, skin microbes with no noticeable effect, and pathogens causing infections. Differentiate each interaction as mutualistic, commensal, or parasitic; and analyze how changes in conditions, such as immune suppression, microbiome imbalance, or injury, can shift normally harmless microbes into disease-causing roles.

Benchmark Clarifications:

Clarification 1: Instruction includes mutualistic, commensal, and parasitic interactions.

Clarification 2: Instruction includes conditions under which normally harmless microorganisms contribute to disease.

Clarification 3: Instruction includes balance and imbalance of microbial communities.

Clarification 4: Instruction includes context-dependent microbial effects on health.

SC.912.MO.8.5 Evaluate how changes in microbial communities influence human health and disease risk.

Benchmark Clarifications:

Clarification 1: Instruction includes disruption of microbial communities through illness, antibiotic use, or lifestyle factors.

Clarification 2: Instruction includes links between microbial imbalance and increased disease susceptibility.

Clarification 3: Instruction includes interactions among microorganisms, immune function, and body systems.

Clarification 4: Instruction includes the long-term health implications of altered microbial relationships.

Clarification 5: Instruction includes interpreting microbiome and health datasets to evaluate relationships among microbial communities, human health, and disease risk. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.9 Analyze how microorganisms are used in food production, medicine, industry, and environmental management.

SC.912.MO.9.1 Explain how microorganisms are used in food production and preservation.

Example: Investigate how bacteria and fungi are intentionally used in food production through fermentation by examining familiar foods such as yogurt, cheese, bread, and fermented vegetables. Using short case studies, visuals, or food ingredient labels, explain

how microorganisms contribute to flavor, texture, and shelf life and how controlled microbial growth supports food safety and the prevention of spoilage.

Benchmark Clarifications:

Clarification 1: Instruction includes fermentation by bacteria and fungi.

Clarification 2: Instruction includes food safety and prevention of spoilage.

SC.912.MO.9.2 Explain how microorganisms are used in medicine and human health applications.

Benchmark Clarifications:

Clarification 1: Instruction includes microorganisms used in the production of antibiotics, vaccines, and therapeutic compounds.

Clarification 2: Instruction includes beneficial microbes and probiotic applications.

Clarification 3: Instruction includes large-scale microbial cultivation for medical use.

Clarification 4: Instruction includes examining historical discoveries, technological advances, and scientific contributions that led to the development of antibiotics, vaccines, probiotics, and other microbial applications in medicine and human health. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.9.3 Analyze how microorganisms are applied in industrial processes.

Benchmark Clarifications:

Clarification 1: Instruction includes microbial use in the production of enzymes, biofuels, and biochemicals.

Clarification 2: Instruction includes industrial fermentation and bioreactors.

SC.912.MO.9.4 Analyze how microorganisms are used in environmental management and sustainability.

Benchmark Clarifications:

Clarification 1: Instruction includes bioremediation of pollutants in soil and water.

Clarification 2: Instruction includes wastewater treatment and waste decomposition.

Clarification 3: Instruction includes microbial roles in nutrient recycling and ecosystem restoration.

Clarification 4: Instruction includes environmental benefits of microbial solutions.

Clarification 5: Instruction includes evaluating evidence describing effectiveness of bioremediation and restoration programs. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.9.5 Evaluate benefits and limitations of using microorganisms in human applications.

Example: Case Study – The City of Orlando's Iron Bridge Water Reclamation Facility uses microorganisms in activated-sludge systems to break down organic waste before treated water is released into the environment. These microorganisms require carefully managed conditions such as adequate oxygen levels, stable temperatures, balanced nutrients, and consistent energy input to function effectively, especially during Florida's heavy rainfall events and seasonal population increases.

Student Task(s) –

Evaluate the benefits of microbial wastewater treatment including efficiency and reduced chemical use.

Analyze limitations related to environmental dependency.

Evaluate long-term sustainability and risk management challenges in Florida's climate.

Benchmark Clarifications:

Clarification 1: Instruction includes efficiency, cost, and environmental impact.

Clarification 2: Instruction includes safety, regulation, and ethical considerations.

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Clarification 3: Instruction includes long-term sustainability and risk management.

Clarification 4: Instruction includes evaluating quantitative performance data associated with microbial technologies to assess effectiveness, efficiency, sustainability, and risk. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.10 Analyze how anthropogenic activities influence microbial populations and processes, and how microbial responses affect ecosystems and human systems.

SC.912.MO.10.1 Explain how anthropogenic activities alter microbial populations and community composition.

Example: Investigate fertilizer application at a central Florida citrus grove or a north Florida row-crop farm where nitrogen and phosphorus fertilizers are routinely applied to increase crop yield. Using soil nutrient data, maps, or short readings, explain how fertilizer inputs alter soil conditions and drive changes in microbial diversity, abundance, and activity within agricultural fields and nearby water systems.

Benchmark Clarifications:

Clarification 1: Instruction includes the impacts of agriculture, urbanization, industrial activity, and waste management.

Clarification 2: Instruction includes nutrient inputs, habitat modification, and pollution.

Clarification 3: Instruction includes changes in microbial diversity, abundance, and activity.

Clarification 4: Instruction includes interpreting land-use, nutrient-input, and microbial-diversity datasets to evaluate relationships between anthropogenic activities and microbial community change. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.MO.10.2 Analyze how anthropogenic environmental changes influence microbial metabolic processes.

Benchmark Clarifications:

Clarification 1: Instruction includes changes in temperature, oxygen availability, and nutrient levels.

Clarification 2: Instruction includes changes in aerobic and anaerobic microbial activity.

Clarification 3: Instruction includes altered rates of decomposition and nutrient cycling.

Clarification 4: Instruction includes the connection between microbial metabolism and ecosystem processes.

SC.912.MO.10.3 Explain how microbial responses to anthropogenic activities affect ecosystem structure and function.

Benchmark Clarifications:

Clarification 1: Instruction includes effects on primary productivity and food webs.

Clarification 2: Instruction includes changes in nutrient availability and cycling.

Clarification 3: Instruction includes ecosystem stability, resilience, and balance.

Clarification 4: Instruction includes the connection between microbial metabolism and ecosystem processes.

Clarification 5: Instruction includes constructing and interpreting systems models that connect microbial responses to ecosystem-level changes. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.10.4 Analyze how altered microbial activity influences human systems and health.

Example: Case Study – In Florida healthcare facilities widespread use of antibiotics has unintentionally altered microbial communities by reducing susceptible bacteria while allowing antibiotic resistant microbes to survive and spread. This change in microbial activity has increased disease risk leading to harder to treat infections and placing

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additional strain on public health systems demonstrating how human actions can unintentionally reshape microbial systems with direct impacts on human health.

Student Task(s) –

Analyze how altered microbial activity increases disease risk.

Evaluate how well-intended human actions can produce unexpected microbial responses.

Identify the connection between microbial change and impacts on human health systems.

Benchmark Clarifications:

Clarification 1: Instruction includes impacts on water quality, soil fertility, and food systems.

Clarification 2: Instruction includes the effects on ecosystems services that support human populations.

Clarification 3: Instruction includes impacts of altered microbial communities on disease transmission, antibiotic resistance, and public health.

Clarification 4: Instruction includes evaluation of scientific evidence describing microbial impacts on human systems. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.MO.10.5 Evaluate strategies for managing anthropogenic impacts on microbial processes to support ecosystem and human sustainability.

Example: Analyze a Florida specific case study focused on the Florida Everglades where large scale wetland restoration and water management projects aim to restore natural nutrient flows and microbial activity. Evaluate how restoration strategies such as removing excess phosphorus inputs, restoring historic water flow, and conserving wetlands support microbial nutrient cycling while also balancing human needs like flood control, agriculture, and the supply of clean water.

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Benchmark Clarifications:

Clarification 1: Instruction includes sustainable land use, pollution reduction, and resource management.

Clarification 2: Instruction includes evaluating trade-offs among environmental, economic, and societal considerations in microbial management strategies.

Clarification 3: Instruction includes comparing observed outcomes with predicted restoration or management goals.

Clarification 4: Instruction includes constructing and evaluating models that predict the outcomes of restoration and management strategies on microbial processes, ecosystem function, and human sustainability. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

Applying the Science of Life

How scientific understanding of living systems is used to improve health, manage resources, solve biological problems, and make informed decisions.

Grades 9-12

SC.912.ASL.1 Apply principles of the science of life to analyze and propose solutions to real-world challenges involving health, ecosystems, food systems, and biological resources.

SC.912.ASL.1.1 Analyze real-world challenges using core principles related to the science of life.

Example: Analyze soil health challenges affecting Florida food systems, such as nutrient-poor sandy soils, soil compaction, or loss of soil microbes in agricultural regions such as the Everglades Agricultural Area or central Florida vegetable farms. Use principles of

matter cycling, energy flow, growth, and biological regulation to explain the biological causes and constraints limiting soil productivity and how soil health influences sustainable food production in Florida.

Benchmark Clarifications:

Clarification 1: Instruction includes biological principles related to structure and function, energy flow, matter cycling, growth, and regulation of living things.

Clarification 2: Instruction includes challenges related to human health, ecosystems, food systems, or biological resource use.

Clarification 3: Instruction includes identification of biological causes and constraints within the challenge related to the science of life.

Clarification 4: Instruction includes interpretation of biological data, evidence, and system models.

SC.912.ASL.1.2 Propose biologically informed solutions to real-world challenges related to the science of life.

Example: Propose biologically informed solutions to improve soil productivity in Florida food systems, such as using cover crops, compost amendments, or mycorrhizal inoculation to address nutrient loss in sandy agricultural soils. Justify solutions by explaining how the strategies align with biological mechanisms, specifically matter cycling, plant-microbe interactions, and growth regulation, while considering feasibility and sustainability in Florida environments.

Benchmark Clarifications:

Clarification 1: Instruction includes solutions grounded in the currently established science of life concepts.

Clarification 2: Instruction includes assessing the reasonableness of solutions, such as feasibility, sustainability, and biological limitations.

Clarification 3: Instruction includes the alignment between proposed solutions and the identified biological mechanisms.

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Clarification 4: Instruction includes comparison of alternative solutions using scientific evidence. Refer to Laboratory Practices Supporting Mastery of 9-12 Life Benchmarks.

SC.912.ASL.2 Use biological evidence, data, and models to evaluate claims, weigh trade-offs, and make informed decisions about biological issues affecting individuals and society.

SC.912.ASL.2.1 Evaluate biological claims using evidence, data, and scientific models.

Example: Evaluate the claim that removing invasive lionfish from Florida coral reef ecosystems aids in the restoration of native fish populations by examining population data, food-web models, and reef ecosystem diagrams. Using the evidence, determine whether the claim is scientifically supported or unsupported and justify the conclusion based on biological data and models.

Benchmark Clarifications:

Clarification 1: Instruction includes analysis of quantitative and qualitative biological data.

Clarification 2: Instruction includes the interpretation of models, diagrams, and simulations.

Clarification 3: Instruction includes distinction between evidence-based claims and unsupported assertions.

Clarification 4: Instruction includes ethical, legal, and societal considerations related to genetic engineering, biotechnology, genomics, gene editing, stem cell research, and biomedical applications.

Clarification 5: Instruction includes distinguishing correlation from causation when evaluating biological claims. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

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SC.912.ASL.2.2 Analyze trade-offs and consequences when making decisions about biological issues.

Example: Analyze the trade-offs involved in managing lionfish populations in Florida coastal waters by considering ecological benefits, economic costs, and impacts on fishing and tourism. Explain short-term and long-term biological consequences of different management decisions while acknowledging uncertainty and limitations in available population data and ecosystem models.

Benchmark Clarifications:

Clarification 1: Instruction includes biological, environmental, and social considerations.

Clarification 2: Instruction includes short-term and long-term consequences.

Clarification 3: Instruction includes the recognition of uncertainty and limitations in biological evidence.

Clarification 4: Instruction includes evaluation of trade-offs using quantitative and qualitative evidence.

SC.912.ASL.3 Explain how humans intentionally use living systems and biological processes in medicine, agriculture, industry, and environmental management.

SC.912.ASL.3.1 Explain how biological processes are applied to medicine and healthcare.

Example: Examine how HeLa cells, derived from Henrietta Lacks, have been used to advance medical research such as cancer treatment development, vaccine testing, and understanding cell division. Explain how knowledge of cellular biology is applied in medicine while also describing the benefits and constraints of using living cells in healthcare, including ethical considerations and limits of biological interventions.

Benchmark Clarifications:

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Clarification 1: Instruction includes the use of biological knowledge in disease prevention, diagnosis, or treatment.

Clarification 2: Instruction includes applications involving cells, microorganisms, or human body systems.

Clarification 3: Instruction includes examining the benefits and constraints of biological interventions. Refer to the Timeline of Key Accomplishments Supporting Mastery of 9-12 Life Benchmarks.

SC.912.ASL.3.2 Explain how living systems are used in agriculture, industry, and environmental management.

Example: Examine how living systems are intentionally used in Florida, such as the use of biological pest control in citrus groves, yeast fermentation in food production, or wetland restoration to manage water quality. Explain how these applications rely on biological processes and evaluate how managing organisms or ecosystems supports agricultural productivity, industrial processes, and environmental stability.

Benchmark Clarifications:

Clarification 1: Instruction includes the use of selective breeding, biotechnology, and biological control methods.

Clarification 2: Instruction includes industrial and agricultural use of living organisms and biological processes.

Clarification 3: Instruction includes the intentional management of ecosystems and biological resources.

SC.912.ASL.3.3 Analyze how scientific techniques are used to collect, preserve, compare, and evaluate forensic evidence.

Example: Compare trace evidence recovered from multiple locations.

Example: Evaluate reliability of different forms of forensic evidence.

Benchmark Clarifications:

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Clarification 1: Instruction includes using fingerprint, biological, and trace evidence.

Clarification 2: Instruction includes chain of custody and contamination prevention.

Clarification 3: Instruction includes analyzing hair, fibers, glass, and soil as evidence.

SC.912.ASL.3.4 Analyze how chemical and biological evidence is used to investigate poisoning, drug exposure, and causes of death.

SC.912.ASL.3.5 Analyze how scientific investigations are used to document, reconstruct, and interpret crime-scene events.

SC.912.ASL.4 Analyze how changes to one part of a biological system can produce intended and unintended consequences across connected systems.

SC.912.ASL.4.1 Analyze cause-and-effect relationships within biological systems.

Example: Analyze how a Florida cattle rancher's management decisions such as grazing intensity, fertilizer use, and manure management affect the cycling of matter, including carbon and nitrogen, within pasture soils, plants and livestock. Explain how these matter-cycling processes create feedback loops that influence soil fertility, animal health, long-term economic viability, and responsible stewardship of land and water resources.

Benchmark Clarifications:

Clarification 1: Instruction includes interactions among living organisms, populations, or biological system components.

Clarification 2: Instruction includes the flow of energy and cycling of matter within biological systems.

Clarification 3: Instruction includes feedback relationships within biological systems.

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Clarification 4: Instruction includes systems models that illustrate feedback relationships and cascading effects. Refer to Modeling Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.ASL.4.2 Analyze intended and unintended consequences of biological interventions.

Example: Analyze how regenerative farming practices used by Florida farmers such as cover cropping, reduced tillage, and compost application are intended to improve soil health and support crop productivity and nutrient availability. Evaluate both intended and unintended consequences of these interventions by explaining the cascading effects on nutrient cycling, soil organisms, nearby ecosystems, and long-term agricultural sustainability beyond the initial practice change.

Benchmark Clarifications:

Clarification 1: Instruction includes anthropogenic change such as technology use and resource management.

Clarification 2: Instruction includes the cascading effects across ecosystems or biological networks.

Clarification 3: Instruction includes the evaluation of system-level outcomes beyond the initial change.

Clarification 4: Instruction includes comparing predicted and observed outcomes of biological interventions.

SC.912.ASL.5 Explore how knowledge of the science of life supports careers and fields such as healthcare, environmental science, nutrition, biotechnology, agriculture, and public health.

SC.912.ASL.5.1 Explain how knowledge of the science of life is applied in career fields.

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Example: Examine how a sports nutritionist working with a South Florida high school cross-country team uses knowledge of metabolism, hydration, digestion, and muscle repair to address fatigue, dehydration, and slow recovery during training in extreme heat and humidity. Explain how biological knowledge is applied to develop nutrition strategies that support energy needs, growth, recovery, and long-term health in student-athletes.

Benchmark Clarifications:

Clarification 1: Instruction includes careers related to: healthcare, environmental science, agriculture, biotechnology, nutrition or public health.

Clarification 2: Instruction includes the use of biological concepts, data, or technologies in professional practice.

Clarification 3: Instruction includes the links between knowledge of the science of life and solving real-world challenges.

Clarification 4: Instruction includes evaluation of real-world datasets, technologies, and evidence used by professionals in life-science careers. Refer to Mathematics Skills Supporting Mastery of 9-12 Life Benchmarks.

SC.912.ASL.5.2 Explain how applications of the science of life impact individuals, communities, and society.

Example: Analyze how applications of the science of life in Florida affect individual health, community well-being, and shared natural resources. Explain how informed civic participation and biological literacy influence public policies, economic choices, and long-term sustainability outcomes at the local and state level.

Benchmark Clarifications:

Clarification 1: Instruction includes the effects on: human health, environmental quality, and resource sustainability.

Clarification 2: Instruction includes ethical, economic, and societal considerations.

Clarification 3: Instruction includes the long-term impact of biological literacy for informed decision-making.

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Clarification 4: Instruction includes using evidence to support informed civic and personal decision-making.

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