Review of Minnesota Academic Standards First Draft by Stan Metzenberg

Thank you for the opportunity to review the Draft Minnesota Science Standards. I recognize that this is a monumental effort for a State, and I congratulate the authors of the draft standards and the Department of Education for producing an outstanding document. While I have attached many suggestions for improvement, the overall tone of the document is scholarly and the coverage of the science is excellent. For the most part, the authors have succeeded in conveying the depth and breadth of learning required, and have maintained a focus on the science content. In looking at the development of the individual strands of science, there are really only a few shortcomings that I detect. The benchmark expectations for student knowledge of chemistry, molecular and cellular biology, and some aspects of physics, do not reach a high enough level in high school. These can be easily corrected.

In the case of the chemistry, this problem is partly caused by the students getting a late start - they should really be introduced to the concept of atoms before the end of elementary school, and should have some basic understanding of chemical principles by the end of middle/junior high school. The content students learn in high school chemistry in many states is quite a bit more advanced than what is reflected in the Minnesota draft, and I include a sampling of Chemistry standards from Indiana, Illinois, Alabama, New Mexico, and California to prove the point. In the draft Minnesota standards, students also get a late start in cell biology, and that makes it difficult for the grade 9-12 standards to rise beyond a superficial treatment of molecular and cellular biology. In the case of the physics, the trajectory of standards and benchmarks seems appropriate up to grade 8, but then fails to realize its potential in high school.

As a point of reorganization, I recommend untangling the integration of standards in middle school/junior high school, so that earth sciences, life sciences, and physical sciences have individual grades in which they are focused in instruction. Without this reorganization, the students will feel the breadth but not the depth of the science. While I have made these suggestions for improvement, I want to reiterate my support for the document as a whole. I think Minnesota students and teachers will be well-served by this document.

Sincerely,

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Minnesota Academic Standards

Science

Public comments on the Science or Social Studies Standards First Drafts are being collected online from the Minnesota Department of Education (MDE) Web site, www.education.state.mn.us or can be faxed, 651-582-8728 or mailed, 1500 Highway 36 West, Roseville, MN 55113, attn: N. Prouty. The public is also encouraged to attend one of the public hearings throughout our state and submit their comments directly.

Grade Level	Strand	Sub-Strand	Standard	Benchmarks
KINDER GARTEN	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will raise questions about the world around them, make careful observations, and seek answers to them.	▪ Students will observe and describe common objects using simple tools. ▪ Students will follow appropriate safety rules concerning the use of goggles, heat sources, electricity, glass, and chemicals and biological materials.
KINDER GARTEN	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will recognize weather changes.	▪ Students will observe and describe daily and seasonal changes in weather.
KINDER GARTEN	IV. LIFE SCIENCE	B. Organisms	The student will understand that there are living and nonliving things.	▪ Students will compare and contrast living and nonliving things.
KINDER GARTEN	IV. LIFE SCIENCE	G. Human Organism	The student will understand that they have five senses.	▪ Students will observe and describe the environment through their five senses.
Comment: I recommend deleting the second bullet point under Kindergarten I-B. Kindergarten students should not be placed in any hazardous situation involving a need for safety goggles, or concern about heat sources, electricity, glass, chemicals and biological materials.				
GRADE 1	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will raise questions about the world around them, make careful observations, and seek answers to them.	▪ Students will observe, describe, measure, compare, and contrast common objects using simple tools.
GRADE 1	II. PHYSICAL SCIENCE	A. Structure of Matter	The student will understand that materials have physical properties.	▪ Students will describe objects in terms of color, size, shape, weight, texture, flexibility, and attraction to magnets.
GRADE 1	II. PHYSICAL SCIENCE	E. Forces of Nature	The student will understand that forces can act at a distance with no substance in between.	▪ Students will observe and describe that magnetism and gravity can affect objects without being touched.
GRADE 1	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	Student will recognize weather cycles.	▪ Students will observe, record, and describe characteristics in daily weather and seasonal cycles.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 1	IV. LIFE SCIENCE	B. Organisms	The student will understand that plants and animals have life cycles.	▪ Students will observe and describe plant and animal life cycles.
GRADE 1	IV. LIFE SCIENCE	D. Heredity	The student will understand there is variation among individuals of one kind within a population and offspring are very much but not exactly like their parents and like one another.	▪ Students will describe ways in which many plants and animals closely resemble their parents. ▪ Students will match adult animals and plants to their offspring.
GRADE 1	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will understand that organisms have basic needs.	▪ Students will observe and describe basic needs of organisms, including, but not limited to, nutrients, air, water and shelter.
GRADE 1	IV. LIFE SCIENCE	G. Human Organism	The student will understand that the human body is made up of parts.	▪ Students will observe and describe major features of the body including, but not limited to, eyes, nose, heart, skin, arms, legs and muscles.
Comments: Grade 1, Standard II-E, I recommend this: " The student will understand that forces can change how something is moving, and can be applied through direct contact (pushes and pulls) or at a distance (gravity and magnetism)" This will allow a better development of the idea of force, in general, and not put too much emphasis on the "no substance in between" issue. Grade 1, Standard IV-B, I recommend this edit to the benchmark: " Students will observe and describe the growth and development of plants and animals." The important aspect of the standard is not the fact of a cycle, per se, but the types of changes that take place during the life of the individual. This helps to bring Standard IV-B into line with the benchmarks under IV-D.				
GRADE 2	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand that science is a human endeavor practiced by civilizations throughout the world.	▪ Students will know that when a science investigation or experiment is repeated, we expect to get a very similar result.
GRADE 2	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will raise questions about the world around them, make careful observations, and seek answers to them.	▪ Students will observe, describe, measure, compare and contrast common objects using simple tools. ▪ Students will organize observable data and describe patterns. ▪ Students will follow appropriate safety procedures in their investigations. For example, the safe use of goggles, heat sources, electricity, glass, and chemicals and biological materials.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 2, Standard I-A. The benchmark makes an important statement, but should be focused more on the standard (and it should be written in passive voice rather than active voice). It is important to set aside the "science as social knowledge" agenda and say that the science results collected in different countries are consistent with the science results collected in the U.S. I recommend: "Students will know that when a science experiment is repeated under identical conditions, even in a different place, it should yield similar results." Grade 2, Standard I-B. The benchmark " Students will organize observable data and describe patterns" might be better written as follows: " Students will organize and interpret data". The reasons are that data are not "observable" per se, and describing patterns in data encourages a bad type of science that could be called "data dredging". The student should interpret the data in the context of some sort of question that led to the data being collected. If they look for patterns in the data, it encourages them to develop a hypothesis and test it with the very same set of data.				
GRADE 2	II. PHYSICAL SCIENCE	A. Structure of Matter	The student will know that materials exist in different states.	▪ Students will observe and identify three states of matter.
GRADE 2	II. PHYSICAL SCIENCE	D. Motion	The student will understand that objects move in various ways.	▪ Students will observe and describe how objects move in a straight line, zigzag, back-and-forth, round-and-round, and fast and slow. ▪ Students will observe that a push, pull, and spin are forces that can make objects move.
Comments: Grade 2, Standard II-A. I recommend that the benchmark be expanded to include transitions of water (for example) between solid, liquid and gas. Examples of this concept in can be seen in Indiana (see Grade 2 #2.3.5) and California (see Grade 1 #1b). This will also help to serve Minnesota's Standard III-B (water cycle). I recommend this benchmark: " Students will know that water can be a solid, liquid, or gas, and can be made to change forms by heating or cooling" Grade 2, Standard II-D. The first benchmark " Students will observe and describe how objects move in a straight line, zigzag, back-and-forth, round-and-round, and fast and slow." is not particularly useful because it isn't clear what knowledge or skill, other than attention span, is being assessed. I recommend getting students to look at the position of objects over time, because this helps to organize how they think about describing motion. For example, the benchmark could be: "Students will observe and describe the positions of moving objects over time, in relation to another fixed object or point in the background"				
GRADE 2	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will understand basic earth materials.	▪ Students will observe and describe the basic earth materials, such as rocks, soils, waters and gases.
GRADE 2	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will understand the water cycle.	▪ Students will observe and describe the cycle of water as it moves through the environment. ▪ Students will observe and describe the relationship between the water cycle and the weather.
GRADE 2	III. EARTH AND SPACE SCIENCE	C. The Solar System	The student will understand some relationships between the earth, moon and sun.	▪ Students will observe that the sun supplies heat and light to the earth. ▪ Students will observe that the sun and the moon are not always in the same place.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 2, Standard III-A. It is not clear what is meant by " The student will understand basic earth materials." What should be understood? Grade 2, Standard III-C. It is not clear what is meant by " The student will understand some relationships between the earth, moon and sun." Some relationships? This is not specific. In addition, the benchmark " Students will observe that the sun and the moon are not always in the same place" does not appear to expect much. I recommend that this benchmark be: " Students will know that as the earth turns, the sun and the moon appear to move in a regular pattern across the sky"				
GRADE 2	IV. LIFE SCIENCE	B. Organisms	The student will understand that plants and animals have life cycles.	▪ Students will observe, describe, compare and contrast plant and animal life cycles.
GRADE 2	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will understand that organisms live in different environments that are suited to their needs.	▪ Students will observe and describe some features that plants and animals have that allow them to live in specific environments.
GRADE 2	IV. LIFE SCIENCE	E. Biological Populations Change Over Time	The student will understand that biological populations change over time.	▪ Students will observe that some kinds of organisms that once lived on earth have completely disappeared, including, but not limited to, dinosaurs, trilobites, mammoths, giant tree ferns, and horsetail trees.
GRADE 2	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will understand some relationships among organisms.	▪ Students will observe and describe predator and prey relationships. ▪ Students will compare and contrast plant eaters and meat eaters.
Comments: Grade 2, Standard IV-B. The benchmark " Students will observe, describe, compare and contrast plant and animal life cycles" is made awkward because of the flood of verbs, none of which explain what is meant. I recommend this: "Students compare the life cycles of animals that go through metamorphic development (e.g. tadpoles/frogs, caterpillars/butterflies) with those that do not (e.g. puppies/dogs)" Grade 2, Standard IV-E. The benchmark needs to use the word "extinction" rather than "disappeared". In any case, the students obviously cannot "observe" what has "disappeared", so that is the wrong verb. I recommend: " Students will know that some species that once lived on earth are now extinct (e.g. trilobites, giant tree ferns, dinosaurs, mammoths, and passenger pigeons)". Grade 2, Standard IV-F. It is not clear what is meant by " The student will understand some relationships among organisms." Some relationships? This is not specific. In addition, the benchmark " Students will compare and contrast plant eaters and meat eaters" needs a better foundation. Students should first learn that ecosystems are based on producers (e.g. plants), and that every living thing that is not a "producer" gets its energy by being a "consumer". Dividing the consumers into primary consumers (i.e. plant eaters) and secondary consumers (meat eaters) is much less important as an ecological classification than producer vs. consumer. There are plenty of organisms (e.g. humans) that are both plant and meat eating.				
GRADE 3	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand the relationship between science and the environment.	▪ Students will understand that science should be used responsibly. ▪ Students will understand that science is a tool that can help investigate and solve environmental concerns.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 3	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will understand the nature of scientific investigations.	▪ Students will ask questions that can be investigated scientifically. ▪ Students will participate in a scientific investigation. ▪ Students choose appropriate tools and materials for measurement, and/or observation and/or construction in scientific investigation. ▪ Students will follow appropriate safety behavior in their investigations. For example, the use of goggles, heat sources, electricity, glass, and chemicals and biological materials.
Comment: Grade 3, Standard I-A. It is not clear what is meant by "science should be used", or what "responsibly" means. Perhaps what is meant is: "Students will understand that scientists have a responsibility to protect the environment".				
GRADE 3	II. PHYSICAL SCIENCE	C. Energy Transformations	Students understand the characteristics and properties of sound and light	▪ Students will explore the different sounds that are produced by changing vibrating objects. ▪ Students will know that sound travels through air, water and other materials. ▪ Students will know that sound can be reflected as an echo. ▪ Students will know that something can be heard when sounds enter the ear. ▪ Students will know that light travels in a straight line until it stopped by an object. ▪ Students will know that light can be reflected. ▪ Students will know that an object in seen when light from the object enters the eye.
Comment: Grade 3, Standard II-C. In the first benchmark, it is not clear what is meant by "changing vibrating objects." What is changing - the vibration or the object? I recommend simply "...are produced by vibrating objects." The fifth benchmark has big scientific correction, which we call refraction, and a very little scientific correction that we call gravitation. I recommend a corrected version that discusses shadows: " Students will know that when light is stopped by an object, a shadow is created".				
GRADE 3	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will describe the properties of rocks and minerals.	▪ Students will group rocks and minerals based on shared physical characteristics.
GRADE 3	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will describe the weather in terms of temperatures, wind speed, wind direction, precipitation, and sky cover.	▪ Students will measure and record weather conditions using common instruments. ▪ Students will identify major cloud types such as cumulus, cirrus, and stratus.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 3	III. EARTH AND SPACE SCIENCE	C. The Solar System	The student will understand the characteristics and relationships of objects in the Solar System.	▪ Students will know that the earth is one of several planets that orbit the sun, and the moon orbits around the earth. ▪ Students will recognize and understand why the appearance of the moon changes over the month. ▪ Students will understand difference between rotation and revolution and their connection to day and night and the year. ▪ Students will identify the relative sizes, distances, movement and basic characteristics of objects in the solar system. ▪ Students will know that the Earth's gravity pulls objects towards it without touching the objects.
Comment: Grade 3, Standard III-A. The benchmark " Students will group rocks and minerals based on shared physical characteristics" should be made more specific, because you want the characteristics to be physical properties that geologists use (e.g. color, hardness) and not other characteristics that should not be used (e.g. size, shape, beauty). I recommend: "Students will group rocks and minerals based on physical properties such as composition, color, and hardness"				
GRADE 3	IV. LIFE SCIENCE	B. Organisms	The student will recognize that plants and animals have different structures that serve different functions.	▪ Students will know plants and animals have structures that serve different functions in growth, survival, and reproduction. ▪ Students will know that plants have different structures from animals that serve the same necessary functions in growth, survival and reproduction. ▪ Students will know examples of diverse life forms in different biomes, such as oceans, deserts, tundra, forests, grasslands, wetlands and some of the structures that allow them to survive in that biome.
GRADE 3	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will understand an organism's patterns of behavior are related to the nature of that organism's environment.	▪ Students will know that many organisms depend on living and dead plants and animals for food. ▪ Students will know organisms interact with one another in various ways besides providing food including, but not limited to, pollination, seed dispersal, and parasite removal. ▪ Students will know changes in an organism's habitat are sometimes beneficial to it and sometimes harmful.
GRADE 3	IV. LIFE SCIENCE	D. Heredity	The student will understand many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment	▪ Students will differentiate between observed characteristics of plants and animals that are fully inherited, and characteristics that are affected by the climate or environment. ▪ Students will identify similarities and differences between parent and offspring.
GRADE 3	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will understand some relationships among organisms.	▪ Students will know energy is transferred through food chains. ▪ Students will compare and contrast herbivores, carnivores, and omnivores. ▪ Students will know that the food animals consume can be traced back to plants.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 3, Standard IV-B. I recommend separating the plants and animals in these benchmarks so that each can be learned well. The attempt to bring them together in single unified physiology is contrived and draws attention away from what needs to be solidly learned. I recommend: Benchmark 1 - "Students will know how roots, stems, leaves, flowers, and seeds are involved in the survival and reproduction of plants" Benchmark 2 - "Students will know how the mouth, lungs, heart, muscles, and brain are involved in the survival and reproduction of animals" Grade 3, Standard IV-C. First benchmark. I recommend reiterating the role of plants as producers: " Students will know that plants depend on sunlight to make their food, and that other organisms must depend on living and dead plants and animals for food." In the second benchmark, I recommend: " Students will know organisms interact with one another in various ways, including providing a source of food, habitat, pollination, seed dispersal, and protection." Grade 3, Standard IV-F. It is not clear what is meant by "The student will understand some relationships among organisms." Some relationships? What does that mean? I also recommend the following changes to the benchmarks: Benchmark 1 - " Students will know matter and energy are transferred between organisms in food chains" Benchmark 2 - " Students will compare and contrast producers (e.g. plants) and consumers (e.g. herbivores, carnivores, omnivores, decomposers). I recommend that you drop the third benchmark, because the concept of "tracing food" doesn't really have a precise meaning.				
GRADE 4	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand the relationship between science and the environment.	▪ Students will understand that science and inventions should be used responsibly. ▪ Students will understand that science is a tool that can help investigate solutions to environmental problems.
GRADE 4	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will participate in scientific investigations.	▪ Students will collect, organize, analyze and present data. ▪ Students will understand that conditions must be kept the same in order to compare investigations. ▪ Students will recognize that evidence and logic, not merely opinion, are necessary to support scientific understandings. ▪ Students will choose appropriate tools and materials for measurement, and/or observation and/or construction in scientific investigation. ▪ Students will follow appropriate safety rules in their investigations. For example, the use of goggles, heat sources, electricity, glass, and chemicals and biological materials.
Comments: Grade 4, Standard I-B. Benchmark 1 - I recommend "hypothesis" before "data collection", as in: "Students will make a hypothesis, then collect, interpret, and present their data" Benchmark 2 - some conditions should be the same, but obviously there are variables too. I recommend: "Students will understand that experimental results are only comparable if one condition is allowed to vary, and the rest of the conditions are kept the same".				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 4	II. PHYSICAL SCIENCE	A. Structure of Matter	The student will know that materials exist in different states and can change from one to another.	▪ Students will distinguish between three states of matter. ▪ Students will know that matter can change and exist in one or more states. ▪ Students will know that heating and cooling can cause a change between states. ▪ Students will know that solids have a definite shape and that liquids take the shape of their container.
Comments: Grade 4, Standard II-A. This is one of the few times that I would recommend a completely different approach. The issue of states of matter already appears in grade 2, and I don't think the first three benchmarks listed here for grade 4 develop the idea further. The fourth benchmark is an inadequate definition of solids vs. liquids. Students obviously know the common meaning of "solid" and "liquid", and the scientific definition is related to the atomic and molecular properties, not taking "the shape of the container". At this point in the development of physical science concepts, it is critical to introduce the idea of the atom. It should be introduced at a very low level, of course, but it allows development of correct scientific vocabulary and concepts. Students need only learn that there are particles too small to see, which we call atoms, and that the atom has a charged nucleus and electrons. That vocabulary will help teachers explain the electric current in the physical science standards that follow. I don't know how they could adequately explain electric currents or static electricity without using the word "electron" at some point, and I don't think "electron" should be presented without "atom". This change would also resolve a serious problem with the benchmarks in later grades, where the idea of "elements" is introduced before atoms. Students cannot easily get to the age of nine without having heard the word "atom" in common language. There is no credible research that students cannot enjoy learning a few facts about the atom in elementary school. It is not a "rote" definition, but a concept about matter they can really think about. The atom is introduced in grade 3 in California, with great success, and appears in grade 1 in the Core Knowledge School curriculum. I would recommend the following different standard and benchmarks for Grade 4, II-A Structure of Matter: Standard: The student will know that there are particles of matter that are too small to see with the eye, called atoms. Benchmarks: • Students will know that matter is made of atoms. • Students will know that atoms have a charged nucleus and electrons.				
GRADE 4	II. PHYSICAL SCIENCE	C. Energy Transformations	The student will understand basic electricity and its application in everyday life.	▪ Students will know that an electrical circuit requires a complete loop through which an electric current can pass. ▪ Students will demonstrate simple electrical circuits using components such as wires, batteries and bulbs. ▪ Students will identify objects and materials that conduct electricity and objects and materials that are insulators. ▪ Students will know how to produce and study the effects of static electricity.
GRADE 4	II. PHYSICAL SCIENCE	E. Forces of Nature	The student will know that a relationships exists between electricity and magnetism.	▪ Students will demonstrate how a wire and magnet can be used to generate electric current. ▪ Students will demonstrate how an electric current can make something magnetic.
GRADE 4	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will understand that water on Earth cycles and exists in many forms.	▪ Students will be able to explain and describe the water cycle involving the processes of evaporation, condensation, precipitation, and collection. ▪ Students will describe the role of the sun in the water cycle. ▪ Students will describe the distribution of water on Earth. ▪ Students will describe the quality of water using physical characteristics.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 4	III. EARTH AND SPACE SCIENCE	D. The Universe	The student will understand the patterns and movements of celestial objects in the sky.	▪ Students will observe that the patterns of stars in the sky appear to slowly move from east to west across the sky nightly and different stars can be seen in different seasons and locations. ▪ Students will know that planets look like stars but over time they appear to wander among the constellations. ▪ Students will understand that stars are like the Sun, some being smaller and some larger, but so far away that they look like points of light. ▪ Students will know that telescopes magnify distant objects in the sky and dramatically increase the number of stars we can see.
Comments: Grade 4, Standard III-D, Benchmark 2. I recommend "Students will know that with the unaided eye, planets look like stars, but over time they appear to move in the fixed background of stars" Benchmark 3. It is not so much that stars are like the sun, but that the sun is a star. I recommend "Students will know that the sun is an average-sized star, and that the other stars are so far away that they look like points of light."				
GRADE 4	IV. LIFE SCIENCE	A. Cells	The student will know that all organisms are composed of cells, which are the fundamental units of life, some organisms are single cells, but other organisms are multi-cellular	▪ Students will understand that cells are very small and will utilize a microscope to observe single cell organisms and single cells within a multi-celled organism ▪ Students will know that all living things consist of one or more cells. ▪ Students will know that cells need food, water and air; a way to dispose of waste; and an environment that they can live in. ▪ Students will know that cells vary greatly in appearance and perform very different roles in an organism.
GRADE 4	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will know that living things can be sorted into groups in many ways according to their varied characteristics and structures.	▪ Students classify plants and animals according to their physical characteristics. ▪ Students learn that features used for grouping depend on the purpose of the grouping.
GRADE 4	IV. LIFE SCIENCE	G. Human Organism	The student will understand the function of basic organs, major systems, growth and development of the human body.	▪ Students will identify the major organs of the following systems: digestive, circulatory, nervous, skeletal/muscular, and respiratory, within the human body. ▪ Students will identify the functions of the major organs and the systems of the human body. ▪ Students will know there is a usual sequence of physical and mental development among human beings.
Comments: Grade 4, Standard IV-C. The classification of plants and animals needs to be based on scientific characteristics - not aesthetic characteristics or an invented classification system that has no scientific value (same problem with Grade 3, Standard III-A.) I recommend "Students classify plants and animals according to their physical characteristics (e.g. using a dichotomous key used to classify plant leaves or insects)."				

Grade Level	Strand	Sub-Strand	Standard	Benchmarks
GRADE 5	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will develop an expectation that there is order in the natural world and it is discoverable.	▪ Students will understand that when a science investigation or experiment is repeated, a similar result is expected.
			The student will understand the usefulness and consequences of science in our interaction with the natural world.	▪ Students will understand that science is a tool that can help investigate solutions to environmental problems. ▪ Students will understand that science should be used responsibly.
GRADE 5	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will understand the process of scientific investigations.	▪ Students will perform a controlled experiment using a specific step-by-step procedure. ▪ Students will support their statements with evidence from various sources. ▪ Students will choose appropriate tools and materials for measurement, and/or observation and/or construction in scientific investigation. ▪ Students will follow appropriate safety behavior in their investigations. For example, the use of goggles, heat sources, electricity, glass, and chemicals and biological materials.
Comments: Grade 5, Standard I-A. I don't know what is meant by "develop an expectation", or even "that there is order". Our perception of order is more religious and philosophical than scientific. It goes right along with "things happen for a reason" as a non-scientific concept. Perhaps the idea of the standard should just be "People can learn about the natural world through well-designed scientific investigations." For the benchmark, I recommend (same as in grade 2): "Students will know that when a science experiment is repeated under identical conditions, even in a different place, it should yield similar results."				
GRADE 5	II. PHYSICAL SCIENCE	C. Energy Transformations	The student will understand that energy exists in many forms and can be transferred in many ways.	▪ Students will know that heat can move from one object to another by conduction and that some materials conduct heat better than others. ▪ Students will know that things that give off light also give off heat. ▪ Students will know that things that absorb light collect heat and may become warmer.
GRADE 5	II. PHYSICAL SCIENCE	D. Motion	The student will understand the principles and advantages provided by simple machines.	▪ Students will use the principle of a simple machine to describe the use of levers, incline plane, wheel and axel.
GRADE 5	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will understand that the surface of the earth changes due to slow processes, such as erosion and weathering, and rapid processes, such as landslides, volcano eruptions, and earthquakes.	▪ Students will recognize the natural processes that cause rocks to break down into smaller pieces. ▪ Students will explain how waves, wind, water, and ice shape and reshape the earth's surface. ▪ Students will describe how humans prepare for and react to rapid Earth processes such as floods, tornadoes, earthquakes, and volcanoes. ▪ Students will recognize the different composition and properties of soil. ▪ Students will describe how humans prepare for and react to erosion.
Comments: Grade 5, Standard II-C. I recommend caution in using the word "heat" as if it were a substance that can be moved (like the pre-19th century model of "caloric"). Heat is a form of energy (thermal energy), and it is better to say that it "flows" (like energy). The Physics Dept. at Univ. of Minnesota will thank you. It would be better to add one more benchmark: "Students will know that heat is a form of energy, and when it is absorbed the temperature of a substance may increase"				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 5	IV. LIFE SCIENCE	E. Biological Populations Change Over Time	The student will know biological populations change over time.	▪ Students will know that individuals of the same species differ in their characteristics, and sometimes the differences give individuals an advantage in surviving and reproducing and pass those differences on to successive generation. ▪ Students will know extinction of a species occurs when the environment changes and adaptive characteristics of a species are insufficient to allow its survival ▪ Students will know that fossils can be compared to one another and to living organisms according to their similarities and differences.
GRADE 5	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will know that matter and energy flow into, out of, and within a biological system.	▪ For a given ecosystem in Minnesota, students will identify major living and non-living components. ▪ Students will understand some source of "energy" is needed for all organisms to stay alive and grow. ▪ Students will understand that food webs describe the relationships among producers, consumers, and decomposers in an ecosystem. ▪ Students will know organisms are growing, dying, and decaying, and their matter is recycled.
Comments: Grade 5, Standard IV-E. Benchmark 1. It is not clear that the characteristic being passed to successive generations is a genetic one, so I recommend splitting this into two benchmarks. First: "Students will know that individuals of the same species differ in their characteristics, and that some of these characteristics are inherited while others are acquired". Second, I recommend teaching natural selection in the context of negative selection, rather than positive advantage: "Students will know that if an inherited characteristic gives an individual a disadvantage in surviving and reproducing, it may not be easily passed on to successive generations". That will cause the next benchmark (extinction) to make more sense. Grade 5, Standard IV-F. Benchmark 1. This is not expecting much in grade 5. I recommend: "For a given ecosystem in Minnesota, students will identify major producers and consumers, and describe climatic and terrain factors". In benchmark 2, I recommend not putting the word energy in quotation marks.				
GRADE 6	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand that science is a way of knowing about the world that is characterized by empirical criteria, logical argument, and skeptical review.	▪ Students will distinguish between scientific evidence and personal opinion. ▪ Students will explain why scientists often repeat each other's investigations to be sure of their results. ▪ Students will know that scientists assume that nature is the same everywhere and that it is understandable and predictable.
Comment: Grade 6, Standard I-A. Benchmark 3. I would not use the word "nature" here because it is imprecise (and sounds a bit like an invocation of the gods). It would be better to say "Students will know that scientists assume that physical forces are the same everywhere, and that what is learned in one part of the universe can be applied to any other part"				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 6	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will understand that scientific inquiry is used by scientists to investigate the natural world in systematic ways.	▪ Students will identify questions that can be answered through scientific investigation and those that cannot. ▪ Students will give examples of how different domains of science use differing bodies of scientific knowledge and employ different methods to investigate questions. ▪ Students will know that observations and explanations can be affected by bias or strong beliefs about what should happen in particular circumstances. ▪ Students will understand that a system is an organized group of related objects or components that form a whole.
Comment: Grade 6, Standard I-B. I recommend deleting benchmarks 3 and 4. Benchmark 3 is a footnote to the way science is conducted, and becomes an "anti-establishment" comment if it is given this much attention. Benchmark 4 is a bit too theoretical - students will understand this in practice from learning about physiological systems, and there's no need to push the definition.				
GRADE 6	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will conduct scientific investigations.	▪ Students will use appropriate tools and Systems International units for measuring length, time, mass, volume, and temperature with suitable precision and accuracy. ▪ Students will follow a specific step-by-step procedure for a scientific investigation. ▪ Students will present and explain data and findings using multiple representations including tables, graphs, physical models, and demonstrations. ▪ Students will use appropriate technology and mathematics skills to access, gather, store, retrieve and organize data. ▪ Students will explain how the student's scientific investigations relate to established scientific principles. ▪ Students will apply established safety rules and guidelines in conducting scientific investigations inside and outside the classroom.
GRADE 6	I. HISTORY AND NATURE OF SCIENCE	C. Scientific Enterprise	The student will know that science and technology are highly vigorous human efforts that both influence and are influenced by civilizations worldwide.	▪ Students will know that people of all backgrounds and with diverse interests, talents, qualities, and motivations engage in fields of science and engineering. ▪ Students will identify different disciplines of science and engineering. ▪ Students will understand that scientists sometimes work in teams and sometimes work alone, but all communicate extensively with others. ▪ Students will know that colleges and universities, business and industry, research institute and governmental agencies are major settings in which scientists and engineers work. ▪ Students will explain that technology is the application of science in order to find solutions to societies' wants and needs. ▪ Students will identify appropriate problems that can be solved using technological design or scientific inquiry.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 6	I. HISTORY AND NATURE OF SCIENCE	D. Historic Perspectives	The student will understand how scientific discovery, culture, societal norms, and technology have influenced one another in different time periods.	▪ Students will cite examples of various individuals throughout history who made discoveries and contributions in science and technology. ▪ Students will relate student experiences in scientific investigation to the experiences of scientists throughout history.
Comment: Grade 6, Standard I-C. In general, I think too much emphasis is being given to History and Nature of Science in this grade. Some of it is repetitive from other grades, but much of it is repetitive just across grade 6. I recommend that the authors try to distill the strand down to about half of its present size, so that it is a better balance with the content areas that follow. Some suggestions are: • Eliminate Benchmark 2 from Grade 6, Standard I-D "Students will relate student experiences ..." (because it is not particularly meaningful). • Combine Benchmark 1 from Grade 6, Standard I-D "Students will cite examples of various individuals" with Benchmark I from Grade 6, Standard I-C "Students will know that people of all backgrounds..." • Combine Benchmark 6 from Grade 6, Standard I-C "Students will identify appropriate problems..." with Benchmark 1 from Grade 6, Standard I-B " Students will identify questions that can be answered..." • Combine Benchmark 2 from Grade 6, Standard I-B " Students will give examples of how different domains of science..." with Benchmark 2 of Grade 6, Standard I-C " Students will identify different disciplines of science and engineering..." • Eliminate Benchmark 3 ("Students will understand that scientists ...") and Benchmark 5 ("Students will explain that technology...") from Grade 6, Standard I-C because neither are strictly true. • Combine Benchmarks 3 and 4 from the second section of Grade 6, Standard I-B ("Students will present and explain data..." and " Students will use appropriate technology...")				
GRADE 6	II. PHYSICAL SCIENCE	A. Structure of Matter	The student will use the idea that matter is made of small particles called atoms to explain that matter can exist in different states and that each state exhibits distinct physical properties.	▪ Students will know that matter can exist as solid, liquid, gas or plasma. ▪ Students will know that a change in temperature or pressure can change the state of a substance. ▪ Students will know that there are about one hundred different elements with unique properties that combine in many ways.
Comment: Grade 6, Standard II-A. Benchmark 1 - I recommend not including plasmas here because it does not build towards an understanding of the standard. Save it for a later grade. Benchmark 2, I recommend an improved linking to the standard: " Students will know that a change in temperature or pressure changes how the atoms or molecules in a substance are packed, which explains changes in state between solid and liquid and gas" Benchmark 3, I recommend being more precise and not mixing the chemical properties into this "physical property" standard. As follows: "Students will know that an element is made up of only one type of atom, and that there are more than one hundred different elements (types of atoms) represented on the Periodic Table"				
GRADE 6	II. PHYSICAL SCIENCE	B. Chemical Reactions	The student will use the idea that matter is made of small particles called atoms to explain how matter combines in a variety of ways to form all living and non-living substances.	▪ Students will give examples of elements, compounds and mixtures. ▪ Students will classify a substance as a mixture or pure substance.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comment: The point of this standard should not be to address living vs. non-living substances (as if there were a physical manifestation of vitalism). I recommend a more foundational standard and set of benchmarks, because this needs to be developed with greater care: Standard: "The student will know that atoms can combine to form molecules, and that chemical reactions are rearrangements or exchanges of the atoms in molecules" • Students will give examples of substances that are pure elements, mixtures of elements, and chemical compounds. • Students will know that molecules are combinations of atoms • Students will know that chemical reactions are rearrangements or exchanges of atoms in molecules				
GRADE 6	II. PHYSICAL SCIENCE	C. Energy Transformations	The student will understand that energy is a property and cannot be created or destroyed, but only changed from one form into another.	▪ Students will know that energy exists as heat, chemical energy, mechanical energy and electrical energy. ▪ Students will recognize that most of what goes on in the universe from exploding stars and biological growth to the operation of machines and the motion of people involves some form of energy being transformed into another. ▪ Students will recognize that energy in the form of heat is almost always one of the products of energy transformation. ▪ Students will identify different forms of energy in everyday situations. ▪ Students will identify transformations of energy from one form to another in everyday situations. ▪ Students will know that energy in stored in many ways.
Comment: I would not recommend saying that energy is a "property", and I would keep the standard as a simple expression of the first law of thermodynamics: "The student will understand that energy cannot be created or destroyed" Then, have these benchmarks, which pretty much cover the same ground. I also recommend that this standard be moved up to grade 8, where it can be taught in the context of chemistry: ▪ Students will know that energy takes different forms, including heat, chemical energy, mechanical energy and electrical energy. ▪ Students will give "everyday" examples of one form of energy being transformed into another form, or being stored ▪ Students will know that an energy transformation may involve the release or absorption of heat.				
GRADE 6	II. PHYSICAL SCIENCE	D. Motion	The student will understand the nature of force and motion.	▪ Students will use a frame of reference to describe the position, direction, speed and motion of an object. ▪ Students will determine the average speed of an object by measuring distance and time. ▪ Students will know the difference between average speed versus speed at a particular time.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 6	II. PHYSICAL SCIENCE	E. Forces of Nature	The student will understand that the structure and motion of objects in the universe are governed by different forces.	▪ Students will know that every object exerts gravitational force on every other object. ▪ Students will know that gravitational force between two objects depends on how much mass the objects have and on how far apart they are. ▪ Students will know that gravitational force is hard to detect unless at least one of the objects has a lot of mass. ▪ Students will know that electric currents and magnets can exert a force on certain objects and each other. ▪ Students will recognize that gravitational forces are weak compared to electric and magnetic.
GRADE 6	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will understand the Earth's composition and structure.	▪ Students will know that the Earth is comprised of layers including the lithosphere, hydrosphere, and atmosphere.
Comment: Grade 6, Standard III-A. Benchmark. To match the standard, this should probably be " Students will know that the Earth is composed of layers, including the lithosphere, mantle, and core".				
GRADE 6	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will understand how the atmosphere interacts on Earth.	▪ Students will identify the composition and structure of the atmosphere. ▪ Students will recognize that air masses circulate in the atmosphere. ▪ Students will describe the temperature and pressure variations that exist in the layers of the atmosphere.
Comment: Grade 6, Standard III-B. It's not clear what is meant by "...the atmosphere interacts on earth". Perhaps what was meant was "The student will understand how weather and climate are related to the composition and structure of the atmosphere"? I also recommend bringing down the benchmarks from this sub-strand in grade 8: ▪ Students will understand how radiation, conduction and convection of energy in and out of the atmosphere affects weather and climate. ▪ Students will know that the wind, ocean currents, and layers of the atmosphere are produced by gravitational forces and unequal heating of the Earth. ▪ Students will demonstrate how the rotation of the Earth affects the winds and ocean currents. • Students will predict or forecast the weather based on collected data.				
GRADE 6	III. EARTH AND SPACE SCIENCE	C. The Solar System	The student will understand the composition and structure of the solar system and the Earth's place in it.	▪ Students will compare the characteristics of Earth with the characteristics and movement patterns of the other planets, their satellites, and other objects in our Solar System. ▪ Students will know that the Sun is a medium-sized star and is the closest star to Earth. It is the central and largest body in the Solar System and is located at the edge of a galaxy. ▪ Students will explain the length of day, length of year, phases of the Moon, eclipses, tides and shadows through the regular and predictable motions of the Earth and Moon.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 6	IV. LIFE SCIENCE	A. Cells	The student will understand that all organisms are composed of cells, which are the fundamental units of life that carry on the many functions needed to sustain life.	▪ Students will know that cells are the fundamental units of life. ▪ Students will know that most organisms are single cells. ▪ Students will know that all organisms are composed of cells.
Comments: Grade 6, Standard IV-A. This is not appear to be developed beyond what was seen in grade 4 (Standard IV-A). I recommend moving the sub-strand into Grade 7, where it can be more adequately combined with other standards. I will make some suggestions for better language in that grade.				
GRADE 6	IV. LIFE SCIENCE	B. Organisms	The student will understand living systems, at all levels of organization, demonstrate the complementary nature of structure and function.	▪ Students will know a variety of body plans and external structures in plants and animals that serve specific functions for survival.
Comments: Grade 6, Standard IV-B. Once again, this is not well developed beyond what was seen in an earlier grade (Grade 3, Standard IV-B). I recommend moving the sub-strand into Grade 7, where it can be taught to a reasonable level of sophistication with other related standards.				
GRADE 6	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will understand that within the diversity of living organisms, patterns of similarities, differences and complex interactions exist between organisms and with the physical environment.	▪ Students will identify organisms that interact with each other as producers, consumers, and decomposers in a food chain. ▪ Students will identify organisms that interact with each other as herbivores, carnivores, and omnivores through food webs. ▪ Students will compare/contrast predator/prey, parasite/host, producer/consumer relationships. ▪ Students will classify organisms based on the details of external features. ▪ Students will know that all individuals of a species that exist together at a given place and time make up a population, and all populations living together and the physical factors with which they interact compose an ecosystem.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 6, Standard IV-C. The first four benchmarks do not adequately develop the subject beyond previous grades. I recommend excising them and splitting the fifth benchmark into progressive levels. I think that this standard does not need to be moved up a grade, but that several of the benchmarks from grade 8 should be brought down and combined: • Students will know that an ecological population is a group of individuals of the same species, living together. • Students will know that an ecological community is a group of populations of species. • Students will know that an ecosystem is comprised by biotic factors (communities) and abiotic environmental factors (e.g. soil, water), and their interactions • Students will be able to taxonomically group organisms to the appropriate kingdom. • Students will know that living and nonliving factors affect the number and types of organisms that an ecosystem can support. ▪ Students will explain how energy is transferred through food chains and food webs in an ecosystem. ▪ Students will explain how the amount of useable energy available to organisms decreases as it passes through a food chain and/or food web. • Students will know that the total amount of matter in a closed system remains the same as it is transferred between organisms and the physical environment even though the matters location or form changes.				
GRADE 6	IV. LIFE SCIENCE	D. Heredity	The student will understand that heredity information is contained in genes that determine characteristics of organisms that are inherited.	▪ Students will know that some traits are inherited and other result from interactions with the environment. ▪ Students will know that reproduction is a characteristic of all living things and why it is essential for the continuation of a species.
Comment: Grade 6, Standard IV-D. Once again, this is not well developed beyond what was seen in grades 2 and 3. I recommend moving the sub-strand into Grade 7, where it can be taught to a reasonable level of sophistication with other related standards.				
GRADE 7	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand that science is a way of knowing about the world that is characterized by empirical criteria, logical argument, and skeptical review.	▪ Students will explain, using examples, that for most core knowledge in science, there is much experimental and observational confirmation. ▪ Students will understand how scientific knowledge is subject to change as new evidence becomes available, or as new theories cause scientists to look at old observations differently. ▪ Students will explain how scientists distinguish among fact, hypothesis, theory and law. ▪ Students will use accepted physical, conceptual, and mathematical scientific models to explain natural phenomena.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 7	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will understand that scientific inquiry is used by scientists to investigate the natural world in systematic ways	▪ Students will know that scientists use different kinds of investigations and methods depending on the questions they are trying to answer. ▪ Students will distinguish among observation, prediction, and inference. ▪ Students will know that hypotheses are valuable even if they turn out not to be true. ▪ Students will know that an understanding of mathematics and the use of technology are essential in determining how a scientific investigation is conducted and the explanations that can be made. ▪ Students will explain why an experiment must be repeated many times and yield consistent results before the results are accepted as correct. ▪ Students will know that systems have boundaries, components, resources, flow and feedback.

Comments:

The History and Nature of Science Strand in Grade 7 is excessive, and needs to be refined. I recommend the following:

- Combine Standard I-A Benchmark 3 ("Students will explain how scientists distinguish...")with Standard I-B Benchmark 2 ("Students will distinguish among ...")
- Eliminate Standard I-B Benchmark 1 ("Students will know that scientists use...") because it is not precise or informative
- Eliminate Standard I-B Benchmark 4 ("Students will know that an understanding of mathematics...") because it is imprecise.
- Eliminate Standard I-B Benchmark 5 ("Students will explain why an experiment must be repeated...") because it has been established in previous grades.
- Eliminate Standard I-B Benchmark 6 ("Students will know that systems have boundaries...") because this development of meta-science is not useful and does not match the standard.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 7	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will design and conduct scientific investigations.	▪ Students will identify a question that can be answered with a scientific investigation with available knowledge and tools. ▪ Students will formulate a testable hypothesis based on prior knowledge. ▪ Students will systematically observe, organize, and record relevant qualitative and quantitative data in a clear and accurate way. ▪ Students will use appropriate tools and Systems International units for measuring length, time, mass, volume, and temperature with suitable precision and accuracy. ▪ Students will recognize that a variable is a condition that may influence the outcome of an investigation and know the importance of manipulating one variable at a time. ▪ Students will write a specific step-by-step procedure for a scientific investigation. ▪ Students will construct reasonable models, predictions and explanations based on collected data or evidence presented in tables or graphs and make inferences based on patterns or trends in the data. ▪ Students will present and explain data and findings using multiple representations including tables, graphs, mathematical and physical models, and demonstrations. ▪ Students will use appropriate technology and mathematics skills to access, gather, store, retrieve and organize data. ▪ Students will explain how the student's scientific investigations relate to established scientific principles. ▪ Students will apply established safety rules and guidelines in conducting scientific investigations inside and outside the classroom.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 7, Standard I-B. The benchmarks need to be edited down to a reasonable size and number. I recommend: • Eliminate benchmark 1 ("Students will identify a question that can be answered...,") because it adds little to previous grades • Keep benchmark 2 because it is the most important ("Students will formulate...") • Eliminate benchmark 3 ("Students will systematically...") because it adds little to previous grades • Eliminate benchmark 4 ("Students will use appropriate tools...") because it adds little to previous grades • Keep benchmark 5 ("Students will recognize that a variable...") • Keep benchmark 6 ("Students will write a specific ...") because it adds "writing" to the "following" of previous grades • Eliminate benchmark 7 ("Students will construct...") because it adds little to previous grades and as written it tends to be inconsistent with hypothesis driven investigations • Eliminate benchmark 8 ("Students will present and explain...") because it adds little to previous grades • Eliminate benchmark 9 ("Students will use appropriate...") because it adds little to previous grades • Keep benchmark 10 ("Students will explain how ...") • Benchmark 11 has been said many times in previous grades. I understand the importance of maintaining a safe lab, but I don't see how repetitively including the same benchmark helps students progress year by year. Perhaps the sentiment in the "safety benchmark" could be expressed in some sort of preamble instead of including it as a benchmark.				
GRADE 7	I. HISTORY AND NATURE OF SCIENCE	C. Scientific Enterprise	The student will know that science and technology are highly vigorous human efforts that both influence and are influenced by civilizations worldwide.	▪ Students will know that the development of technology drives scientific investigation and explanations and that scientific knowledge drives the development of technology.
GRADE 7	I. HISTORY AND NATURE OF SCIENCE	D. Historic Perspectives	The student will understand how scientific discovery, culture, societal norms, and technology have influenced one another in different time periods.	▪ Students will cite examples of various individuals throughout history who made discoveries and contributions in science and technology. ▪ Students will cite examples of how the prevailing culture of a time influenced scientific and technologic advances. ▪ Students will relate student experiences in scientific investigation to the experiences of scientists throughout history.
Comment: I recommend combining the benchmark under Grade 7 Standard I-C into the Sub-strand D because they are not clearly different. I recommend eliminating the third benchmark "Students will relate..." because it does not measure progression of knowledge towards the Sub-strand D standard.				
GRADE 7	II. PHYSICAL SCIENCE	A. Structure of Matter	Use the idea that matter is made of small particles called atoms to explain that matter can exist in different states and that each state exhibits distinct physical properties.	▪ Students will distinguish between mass and volume. ▪ Students will use the properties of substances to classify them into groups with common properties. ▪ Students will compare and contrast the mass, shape and volume of solids, liquids and gases.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 7	II. PHYSICAL SCIENCE	B. Chemical Reactions	The student will use the idea that matter is made of small particles called atoms to explain how matter combines in a variety of ways to form all living and non-living substances.	▪ Students will distinguish among elements, compounds and mixtures.
Comment: Grade 7, Standard II-B. This standard, and the benchmark under it, do not build upon what was covered in grade 6. I recommend eliminating it here and teaching it well in grade 6.				
GRADE 7	II. PHYSICAL SCIENCE	C. Energy Transformations	The student will understand that energy cannot be created or destroyed, but only changed from one form into another.	▪ Students will understand that adding or taking away heat from a system with a constant mass will result in temperature change. ▪ Students will recognize that heat moves in predictable ways, moving from warmer objects to cooler ones until both reach the same temperature. ▪ Students will give examples of the movement of heat by convection, conduction and radiation. ▪ Students will know that energy can be transferred through waves. ▪ Students will know that vibrations move at different speeds in different materials, have different wavelengths, and set up wave-like disturbances that spread away from the source. ▪ Students will know that waves have many different forms, some visible, some not. ▪ Students will demonstrate that light from the sun is made up of a mixture of many different colors of light. ▪ Students will demonstrate that the light given off or reflected by objects is made up of a mixture of colors of light. ▪ Students will know that human eyes respond to visible light, a narrow range of wavelengths of electromagnetic radiation, and that differences of wavelength within that range are perceived as differences in color.
Comments: Grade 7, Standard II-C. The standard is not different from what is seen in Grade 6. I recommend moving it to grade 8, where it can be taught to a more scholarly level and with other related standards. Here are a couple of corrections however: • Benchmark 1 ("Students will understand that adding or taking away heat ...") - this is not strictly true. The heat added to a glass of ice water will not raise its temperature, for example, but will contribute to further melting of the ice. • Benchmark 6 ("Students will know that waves have many different forms, some visible, some not") - It is a bit artificial to distinguish between waves we "see" and waves we "don't see" because waves are not matter - what we see is not a wave, but how the energy in a wave interacts with matter that we can see.				
GRADE 7	II. PHYSICAL SCIENCE	D. Motion	The student will understand the nature of force and motion.	▪ Students will represent the motion of an object on a graph. ▪ Students will interpret distance vs. time graphs. ▪ Students will distinguish between velocity and speed. ▪ Students will know that acceleration is a change in speed or direction.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 7, Standard II-D. This is excellent, but might be better in Grade 8, where students will have more developed math skills, and where it can be combined with other related standards.				
GRADE 7	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will understand Earth's composition and structure.	▪ Students will explain how land forms are created through forces such as folding, faulting, volcanic eruptions, deposition of sediment, and weathering and erosion. ▪ Students will explain how features on the Earth's surface are constantly changing through a combination of slow and rapid processes such as weathering, erosion, sediment deposition, landslides, volcanic eruptions, and earthquakes. ▪ Students will understand the concept of plate tectonics including the organization of the Earth into plates and the processes that move them. ▪ Students will describe the various processes and their interactions that are involved in the rock cycle. ▪ Students will interpret successive layers of sedimentary rocks and their fossils to document the age and history of the Earth. ▪ Students will know how constructive and destructive Earth processes can affect the evidence of Earth's history. ▪ Students will be able to use various characteristics to classify and identify rocks and the minerals that comprise them.
Comments: Grade 7, Standard III-A. I recommend moving this to Grade 6, where it can be combined with the benchmark on earth layers. The lesson on earth shaping and features would fit reasonably well in that grade with ecosystems and evolutionary biology.				
GRADE 7	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will understand how the Earth's atmosphere interacts in the Earth's system.	▪ Students will explain how the processes of evaporation, condensation, and precipitation affect weather patterns. ▪ Students will know that the sun is the principal energy source of winds, ocean currents, and the water cycle. ▪ Students will know that changes in the composition of the atmosphere, ocean temperature, and geologic events can impact the Earth's climate. ▪ Students will explain how the tilt of the Earth's axis and the Earth's revolution around the Sun affect seasons and weather patterns.
Comments: Grade 7, Standard III-B. I recommend moving this to Grade 6, where it can be combined with the benchmarks on water cycle.				
GRADE 7	III. EARTH AND SPACE SCIENCE	C. The Solar System	The student will understand the composition and structure of the solar system and the Earth's place in it.	▪ Students will be able to explain the length of day, length of year, phases of the Moon, eclipses, tides, and shadows through the regular and predictable motions of the Earth and Moon.
Comments: Grade 7, Standard III-C. I recommend moving this to Grade 6, where it can be combined with the benchmarks on solar system.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 7	IV. LIFE SCIENCE	A. Cells	The student will understand that all organisms are composed of cells, which are the fundamental units of life that carry on the many functions needed to sustain life.	▪ Students will distinguish between single and multi-cellular organisms. ▪ Students will distinguish between plant and animal cells. ▪ Students will know that cells repeatedly divide for growth and repair.

Comments:
Grade 7, Standard IV-A. This standard needs to be developed to a much deeper level, because little is being expected here (beyond what is in grade 4). I recommend that this standard be the focal point of cell biology in grades 6-8, and that the grade 6 and grade 8 content be brought together here in grade 7. The key elements in teaching of cell biology at this stage are simple cell structure and mitosis. Most of the functional elements of cell biology can be left for high school, including DNA replication, transcription, and translation, and the functions of lysosomes, endoplasmic reticulum and Golgi. I also recommend delaying teaching of meiosis until high school, where it can be absorbed in the context of Mendel's Laws. I recommend the following standard and benchmarks for the cell biology in middle school. The proposed standard is borrowed from a Grade 8 benchmark:
Standard: The student will understand that cells use energy from food for the production of materials necessary for life, including cell growth and cell division.

- Students will know that all cells have a semi-permeable membrane, and that plant cells also have a cell wall
- Students will know that the mitochondrion helps make the energy from food available, and the chloroplast makes energy from the sun available to plants.
- Students will know that DNA is a molecule that carries genetic information, and that it is primarily found in the nucleus.
- Students will know that mitosis is a way that cells replicate, and that it involves giving identical copies of the DNA to each daughter cell.

GRADE 7	IV. LIFE SCIENCE	B. Organisms	The student will understand living systems, at all levels of organization, demonstrate the complementary nature of structure and function.	▪ Students will explain the organization of whole organisms in a living system including populations, niche, and communities. ▪ Students will explain how organisms are organized into specialized cells, tissues, organs and organ systems that perform specialized functions. ▪ Students will know that organisms can react to internal and environmental stimuli through behavior.

Comment:
Grade 7, Standard IV-B.
Benchmark 1 - this is erroneous at several levels. First, populations and communities should not be called part of a "living system", but you could properly say they were part of an "ecosystem". Second, this benchmark misuses the word "niche" . A niche is not an organizing level for organisms in an ecosystem, along the lines of a population or community. I recommend that this benchmark be eliminated - it is covered in grade 6 and the effort should be focused in that grade.
Benchmarks 2 and 3 - I recommend splitting these into smaller parts, and making this the focus of the standard in grade 7. In addition, the "specialized functions" need some elaboration at this grade, to cause progression of understanding beyond the sub-strand G treatment in grade 4:

- Students will understand how multicellular organisms are based on levels of structure, from cells to organ systems.
- Students will understand how the digestive systems of animals break down food, and how the leaves of plants generate simple sugars using carbon dioxide.
- Students will understand how the vascular systems of plants, and the circulatory systems of animals, are involved in the distribution of nutrients.
- Students will know that plant and animal respiration involves the exchange of carbon dioxide for oxygen, and that plant photosynthesis causes a net production of oxygen.
- Students will explain how flowering plants reproduce sexually.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 7	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will understand that within the diversity of living organisms, patterns of similarities, differences and complex interactions exist between organisms and with the physical environment.	▪ Students will use and create dichotomous keys to classify organisms based on the details of external and /or internal features. ▪ Students will give examples of ways humans can alter the equilibrium of ecosystems, including human population growth, technology, and consumption; human destruction of habitats (through direct harvesting, pollution and atmospheric changes). ▪ Students will give examples of how environmental neglect or degradation can lead to potentially irreversible effects.
Comment: Grade 7, Standard IV-C. Benchmark 1. I recommend that students use dichotomous keys, but not that they create them. This is analogous to asking a student to create an algorithm in mathematics - they are likely to create something that doesn't work, and to fail to learn the intended lesson.				
GRADE 7	IV. LIFE SCIENCE	D. Heredity	The student will understand that heredity information is contained in genes that determine characteristics of organisms that are inherited through asexual and sexual reproduction.	▪ Students will know that inherited traits result from information contained in genes located on chromosomes of each cell. ▪ Students will know that each gene carries a single unit of information and can influence more than one trait. ▪ Students will know that inherited traits can be determined by one or many genes. ▪ Students will identify the criteria established to define and distinguish species. ▪ Students will explain how flowering plants reproduce sexually.
Comments: Grade 7, Standard IV-D. The standard is a bit vague, and uses the noun heredity as if it were an adjective too. The benchmarks should use the word DNA, as well as gene and chromosome. The second benchmark is incorrect - genes do not carry "a single unit of information". I recommend that the fourth benchmark (species) be moved into sub-strand E. I recommend the fifth benchmark (flowering plants) be moved into Sub-strand B, and that sexual vs. asexual propagation be delayed until high school when it can be discussed with more clarity. For this standard and benchmarks, I recommend: Standard: The student will understand that hereditary information is contained in genes, which are made of DNA and organized into chromosomes. • Students will know that inherited traits result from information carried in DNA, which is organized into units called genes. • Students will know that a chromosome is a large segment of DNA that carries many genes • Students will know that people usually have two copies of each chromosome, one inherited from the mother and the other from the father. • Students will know that genetic traits usually depend on the different versions of one or more genes that are inherited from each parent				
GRADE 7	IV. LIFE SCIENCE	E. Biological Populations Change Over Time	The student will understand how evolution provides a scientific explanation for the fossil record of ancient life forms, as well as the striking similarities observed among the diverse species of living organisms.	▪ Students will know the concept of extinction and that extinction is common. ▪ Students will know that fossils document the appearance of many life forms. ▪ Students will give examples how fossils record the diversification of many life forms.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grade 7, Standard IV-E. I would explain this a bit more thoroughly, because this needs to be taught well: Standard: "The student will understand how Charles Darwin's theory of the evolution of species by natural selection provides a scientific explanation for the fossil record of ancient life forms, as well as the striking similarities observed among the diverse species of living organisms." I also recommend bringing benchmarks down from grade 8, and including them in grade 7: ▪ Students will understand how natural selection can lead to adaptive change over a period of many generations ▪ Students will understand how a common ancestry can explain the similarities between some organisms ▪ Students will know criteria that are used to determine whether two individuals are in the same species. • Students will explain how diversity of species can develop through gradual processes over generations				
GRADE 7	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will understand how the flow of energy and the recycling of matter contribute to a stable ecosystem.	▪ Students will know all energy within an ecosystem originates from the sun. ▪ Students will know that plants use the energy in light to make sugars out of carbon dioxide and water. They use or store this food/sugar. Organisms eat plants for the food/sugar and energy, and produce carbon dioxide and water.
Comment: Grade 7, Standard IV-F. I recommend eliminating the standard in this grade. The ecological aspects of the standard are in grade 6, and the physiological aspects are embedded in sub-strands A and B in grade 7.				
GRADE 7	IV. LIFE SCIENCE	G. Human Organism	The student will understand human body systems and their relationship to good health.	▪ Students will give examples of the effects of how environmental factors can lead to diseases and other risks to human health.
Comment: Grade 7, Standard IV-G. Benchmark: The grammar is a bit tangled, and "environmental factors" is a bit non-specific. I recommend: "Students will give examples of how infectious agents, poor nutrition, or exposure to toxic substances can lead to diseases and other risks to human health."				
GRADE 8	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand that science is a way of knowing about the world that is characterized by empirical criteria, logical argument, and skeptical review.	▪ Students will explain how scientific knowledge is subject to change as new evidence becomes available, or as new theories cause scientists to look at old observations differently. ▪ Students will know that science can sometimes be used to inform ethical decisions by identifying the likely consequences of particular actions. ▪ Students will explain how scientific claims are subject to peer review, where scientists evaluate explanations proposed by other scientists by examining and comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, replicating investigations, and suggesting alternative explanations for the same observations. ▪ Students will explain the development, usefulness, and limitations of scientific models in the explanation and prediction of natural phenomena.
Comments: Grade 8, Standard I-A. The first benchmark ("Students will explain how scientific knowledge ...") should be eliminated, as it adds nothing to the grade 7 benchmark.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will understand that scientific inquiry is used by scientists to investigate the natural world in systematic ways.	▪ Students will give examples of how different domains of science use differing bodies of scientific knowledge and employ different methods to investigate questions. ▪ Students will know that scientific investigations involve the common elements of systematic observations, carefully collected, relevant evidence, logical reasoning, and some imagination in developing hypotheses and explanations. ▪ Students will know that an understanding of mathematics and the use of technology are essential in determining how a scientific investigation is conducted and the explanations that can be made. ▪ Students will know that scientists may conduct investigations in a simple system and make generalizations to more complex systems. ▪ Students will know that scientists and engineers have ethical codes regarding living things and impact on the environment.
Comments: Grade 8, Standard I-B. I recommend eliminating the first benchmark ("Students will give examples of how...") as it does not go beyond the grade 6 benchmark. Eliminate Standard I-B Benchmark 3 ("Students will know that an understanding of mathematics...") because it is imprecise. Eliminate Standard I-B Benchmark 4 ("Students will know that scientists may...") because it is imprecise and does not apply to "complexity theory" scientists who do the opposite.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will use multiple skills to design and conduct scientific investigations.	▪ Students will identify a question that can be answered with a scientific investigation with available knowledge and tools. ▪ Students will formulate a testable hypothesis based on prior knowledge. ▪ Students will systematically observe, organize, and record relevant qualitative and quantitative data in a clear and accurate way. ▪ Students will use appropriate tools and Systems International units for measuring length, time, mass, volume, and temperature with suitable precision and accuracy. ▪ Students will specify variables to be changed, controlled, and measured. ▪ Students will use sufficient trials and adequate sample size to ensure reliable data. ▪ Students will write a specific step-by-step procedure for a scientific investigation. ▪ Students will construct reasonable models, predictions and explanations based on collected data or evidence presented in tables or graphs and make inferences based on patterns or trends in the data. ▪ Students will present and explain data and findings using multiple representations including tables, graphs, mathematical and physical models, and demonstrations. ▪ Students will explain how variability affects measurements and calculations. ▪ Students will be able to use appropriate technology and mathematics skills to access, gather, store, retrieve and organize data. ▪ Students will establish cause effect relationships based on gathered and established evidence. ▪ Students will explain how the student's scientific investigations relate to established scientific principles. ▪ Students will be able to apply established safety rules and guidelines in conducting scientific investigations inside and outside the classroom.

Comments:

Grade 8, Standard I-B. The benchmarks need to be edited down to a reasonable size and number. I recommend elimination of benchmarks 1, 2, 3, 4, 7, 8, 9, 10, 12, and 13 because they add little to previous grades. Retain the following benchmarks, which are not redundant:

- Students will specify variables to be changed, controlled, and measured.
- Students will use sufficient trials and adequate sample size to ensure reliable data.
- Students will establish cause effect relationships based on gathered and established evidence.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	I. HISTORY AND NATURE OF SCIENCE	C. Scientific Enterprise	The student will know that science and technology are highly vigorous human efforts that both influence and are influenced by civilizations worldwide.	▪ Students will evaluate the documentation and verifiability of information from a variety of sources. ▪ Students will know that technological solutions have intended benefits and unintended consequences. ▪ Students will use scientific inquiry and the technological design process to solve problems. ▪ Students will know that technological changes and scientific advances are often accompanied by social, political, and economic changes. ▪ Students will recognize that science and technology are influenced by social needs, attitudes, values, and limitations, and cultural backgrounds and beliefs.
Comment: Grade 8, Standard I-C. Combine benchmarks 4 ("Students will know that technological changes...") and 5 ("Students will recognize that ...") into a single benchmark.				
GRADE 8	I. HISTORY AND NATURE OF SCIENCE	D. Historic Perspectives	The student will understand how scientific discovery, culture, societal norms, and technology have influenced one another in different time periods.	▪ Students will cite examples of various individuals throughout history who made discoveries and contributions in science and technology. ▪ Students will cite examples of how the prevailing culture of a time influenced scientific and technologic advances. ▪ Students will relate student experiences in scientific investigation to the experiences of scientists throughout history. ▪ Students will cite examples of how science contributed to revolutions or changes in agriculture, manufacturing, sanitation, medicine, warfare, transportation, information processing, or communication.
Comment: Grade 8, Standard I-D. Eliminate benchmark 2 and 3, as they add little value to benchmarks from previous grades.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	II. PHYSICAL SCIENCE	A. Structure of Matter	The student will use the idea that matter is made of small particles called atoms to explain that matter can exist in different states and that each state exhibits distinct physical properties.	▪ Students will use evidence to explain that matter is made of small particles called atoms, which are too small to see. ▪ Students will describe the states of matter in terms of the space between atoms and/or molecules. ▪ Students will give evidence that the space between atoms and/or molecules is smallest in a solid, and greatest in a gas. ▪ Students will know that equal volumes of different substances usually have different masses. ▪ Students will know that an atom is the smallest unit of an element that maintains the characteristics of the element. ▪ Students will differentiate between an atom and a molecule. ▪ Students will understand that atoms combine to form molecules that are the smallest unit of a compound. ▪ Students will know that all pure substances have characteristic properties of solubility, density, melting point and boiling point and that characteristic properties are independent of the amount of the sample of substance. ▪ Students will use characteristic properties to identify elements and compounds.
Comments: Grade 8, Standard II-A. In this grade, the sub-strand needs to be developed much more deeply. I recommend the following standard and benchmarks: Standard: The student will understand that all forms of matter are composed of one or more types of atoms, and that atoms are composed of protons, neutrons, and electrons. • Students will know the structure of the atom and that it is composed of protons, neutrons, and electrons. • Students will be able to use a Periodic Table to determine the number of protons in an element. • Students will describe the states of matter in terms of the spacing and motions of atoms and/or molecules. • Students will know that pure substances may have characteristic properties of solubility, density, melting point and boiling point.				
GRADE 8	II. PHYSICAL SCIENCE	B. Chemical Reactions	The student will use the idea that matter is made of small particles called atoms to explain how matter combines in a variety of ways to form all living and non-living substances.	▪ Students will distinguish among elements, compounds, and heterogeneous and homogeneous mixtures. ▪ Students will use characteristic properties to separate mixtures. ▪ Students will differentiate between physical changes and chemical changes. ▪ Students will recognize that no matter how substances within a closed system interact, the total mass of the system remains the same. ▪ Students will show how the idea of atoms and molecules explains conservation of mass.
Comments: Grade 8, Standard II-B. The standard is not adequately specific, and the benchmarks do little to develop the foundation of chemical reactions. I recommend this set: Standard: The student will understand that atoms are exchanged or rearranged in chemical reactions, but that they are not created or destroyed in the reactions. • Students will know how to explain the chemical formulas of compounds based on the symbols for the elements. • Students will know how to explain the exchange of atoms represented in a simple chemical reaction equation. • Students will know that the products of a chemical reaction have the same mass as the reactants.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	II. PHYSICAL SCIENCE	C. Energy Transformations	The student will understand that energy is a property and cannot be created or destroyed, but only changed from one form into another.	▪ Students will understand that energy is a property of many substances. ▪ Students will compare and contrast heat energy, chemical energy, mechanical energy and electrical energy. ▪ Students will know that potential energy is stored energy and is associated with gravitational or electrical force, mechanical position, or chemical composition. ▪ Students will differentiate between kinetic and potential energy and identify situations where kinetic energy is converted into potential energy and vise versa. ▪ Students will use the idea that matter is made of small particles to explain the movement of heat in conduction and convection. ▪ Students will know that electromagnetic waves have ranges of wavelengths such as radio waves, microwaves, infrared wave, visible light, ultraviolet light, and x-rays.
Comments: Grade 8, Standard II-C. I recommend bringing up this standard from grade 6, as follows: Standard: "The student will understand that energy cannot be created or destroyed" • Students will know that energy takes different forms, including heat, chemical energy, mechanical energy and electrical energy. • Students will give "everyday" examples of one form of energy being transformed into another form, or being stored as potential energy • Students will know that an energy transformation may involve the release or absorption of heat or light. • Students will know that electromagnetic waves include radio waves, microwaves, infrared, visible light, ultraviolet light, x-rays, and gamma rays • Students will know how wavelength and frequency are related in electromagnetic waves.				
GRADE 8	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will understand Earth's composition and structure.	▪ Students will explain how earthquakes, volcanoes, sea-floor spreading, and mountain building are a result of the movement of crustal plates.
GRADE 8	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will understand how the atmosphere interacts with the Earth system.	▪ Students will understand how radiation, conduction and convection of energy in and out of the atmosphere affects weather and climate. ▪ Students will know that the wind, ocean currents, and layers of the atmosphere are produced by gravitational forces and unequal heating of the Earth. ▪ Students will demonstrate how the rotation of the Earth affects the winds and ocean currents. ▪ Students will predict or forecast the weather based on collected data.
Comment: Grade 8, Standard III-B. I recommend that this standard be moved down to Grade 6, and combined with the same sub-strand.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	III. EARTH AND SPACE SCIENCE	C. The Solar System	The student will understand the composition and structure of the solar system and the Earth's place in it.	▪ Students will know that the Sun is the principle energy source for the solar system and that this energy is transferred in the form of radiation. ▪ Students will know that energy that travels through space in the form of waves as electromagnetic radiation and that some types electromagnetic radiation can be seen as color and others are made of wave lengths that are too long or too short to be seen.
Comment: Grade 8, Standard III-C. I recommend moving the first benchmark ("Students will know that the sun ...") down to grade 6, in the same sub-strand, where it can be taught with greater focus. The second benchmark ("Students will know that energy that travels ...") can be eliminated, because it is effectively covered in Standard II-C of grade 8.				
GRADE 8	III. EARTH AND SPACE SCIENCE	D. The Universe	The student will understand the composition and structure of the universe.	▪ Students will know that the universe consists of many billions of galaxies, each containing many billions of stars and that there are vast distances measured in light years that separate these galaxies and stars from one another and from the Earth. ▪ Students will know common types and life cycles of stars in the universe. ▪ Students will explain how Doppler evidence suggests that our universe is expanding, moving away from the Earth and indicates support for the Big Bang theory of the origin of the universe.
Comment: Grade 8, Standard III-D. I recommend that the third benchmark use the expression "red-shift" instead of the word "Doppler", as follows: "Students will explain how astronomical red-shift indicates that our universe is expanding, and provides support for the Big Bang Theory."				
GRADE 8	IV. LIFE SCIENCE	A. Cells	The student will understand that all organisms are composed of cells, which are the fundamental units of life that carry on the many functions needed to sustain life.	▪ Students will know that cells convert energy from food for the production of materials necessary for life, including cell growth and cell division. ▪ Students will explain that multi-cellular organism have specialized cells that perform specialized functions.
GRADE 8	IV. LIFE SCIENCE	B. Organisms	The student will understand living systems, at all levels of organization, demonstrate the complementary nature of structure and function.	▪ Students will compare and contrast specialized functions of digestion, circulation, respiration, reproduction, excretion, control and coordination and movement in multi-cellular organisms including humans ▪ Students will know that an organism's ability to regulate its internal environment enables it to grow, reproduce and obtain resources in a constantly changing environment. ▪ Students will know that organisms' behavioral response may be determined by heredity and past experience.
Comments: Grade 8, Standard IV-A and Standard IV-B. These should be moved down to grade 7, where they can be considered with greater focus.				

Grade Level	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will understand that within the diversity of living organisms, patterns of similarities, differences and complex interactions exist between organisms and with the physical environment.	▪ Students will give examples of relationships that are mutually beneficial and competitive. ▪ Students will be able to taxonomically group organisms to the appropriate kingdom. ▪ Students will know that living and nonliving factors affect the number and types of organisms that an ecosystem can support. ▪ Students will explain the factors that affect the number and types of organisms an ecosystem can support including available resources; abiotic factors, and disease. ▪ Students will be able to explain how the interrelationships and interdependencies among organisms generate stable ecosystems. ▪ Students will be able to explain how the amount of life an environment can support is limited by the availability of matter, energy, and the ability of the ecosystem to recycle materials.
Comments: Grade 8, Standard IV-C. Most of the benchmarks do not develop the sub-strand much beyond grade 6. I recommend moving the second and third benchmarks down to grade 6, where they can be combined with others, and eliminating benchmarks 1, 4, 5, and 6 as redundant.				
GRADE 8	IV. LIFE SCIENCE	D. Heredity	The student will understand that heredity information is contained in genes that determine characteristics of organisms that are inherited through asexual and sexual reproduction.	▪ Students will compare and contrast the advantages and disadvantages of sexual and asexual reproduction.
Comments: Grade 8, Standard IV-D. This should be moved into grades 9-12 Biology. Without an understanding of meiosis and gamete formation, and fertilization, it is not the right point to present this material.				
GRADE 8	IV. LIFE SCIENCE	E. Biological Populations Change Over Time	The student will understand how evolution provides a scientific explanation for the fossil record of ancient life forms, as well as the striking similarities observed among the diverse species of living organisms.	▪ Students will be able to explain how a species' biological adaptation in structure, function and behavior enhances its reproductive success and survival in a particular environment. ▪ Students will understand that there is scientific evidence of common ancestry among some organisms. ▪ Students will give examples of how characteristics of some species do not allow survival when the environment changes. ▪ Students will give examples of physical characteristics of an organism that changes the organisms' chance of survival. ▪ Students will explain how diversity of species can develop through gradual processes over generations.
Comments: Grade 8, Standard IV-E. Most of the benchmarks do not develop the sub-strand much beyond grade 7. I recommend moving these benchmarks down to grade 7, where they can be presented in a more focused way.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 8	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will understand how the flow of energy and the recycling of matter contributes to a stable ecosystem.	▪ Students will explain how energy is transferred through food chains and food webs in an ecosystem. ▪ Students will explain how the amount of useable energy available to organisms decreases as it passes through a food chain and/or food web. ▪ Students will know that the total amount of matter in a closed system remains the same as it is transferred between organisms and the physical environment even though the matters location or form changes.
Comment: Grade 8, Standard IV-F. I recommend that this sub-strand be moved into grade 6, where it can be taught in the context of Standard IV-C.				
GRADE 8	IV. LIFE SCIENCE	G. Human Organism	The student will understand human body systems and their relationship to good health.	▪ Students will explain how many factors related to human health can be controlled and some cannot be controlled. ▪ Students will know that protection from disease is a specialized function in multi-cellular organisms. ▪ Students will know that disease in organisms can be caused by intrinsic failures of the system or infection by other organisms. ▪ Students will use systematic approach to think critically about risks/benefits of a variety of hazards.
Comment: Grade 8, Standard IV-G. I recommend eliminating this sub-strand at this grade level - it does not build sufficiently on the grade 7 material.				
GRADE 9–12	I. HISTORY AND NATURE OF SCIENCE	A. Scientific World View	The student will understand the nature of scientific ways of thinking and that scientific knowledge changes and accumulates over time, some scientific ideas are incomplete, and opportunity exists in these areas for new advances.	▪ Students will be able to distinguish among hypothesis, theory, and law as scientific terms and how they are used to answer a specific question. ▪ Students will be able to explain how scientific innovations and new evidence can challenge accepted theories and models, including cell theory, atomic theory, theory of evolution, plate tectonic theory, germ theory of disease, Big Bang theory. ▪ Students will know that scientific explanations must meet criteria to be considered valid, including that they must be consistent with experimental and observational evidence about nature, logical, respect the rules of evidence, be open to criticism, and report methods and procedures. ▪ Students will recognize how traditions govern the conduct of science, including ethics, peer review, conflict, and consensus.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	I. HISTORY AND NATURE OF SCIENCE	B. Scientific Inquiry	The student will design and conduct a scientific investigation and evaluate the results of that investigation, understand and use the processes of scientific investigation to design, conduct, describe, and evaluate these investigations.	▪ Students will be able to design and complete a scientific experiment using the scientific method including questioning, testing, hypothesizing, analyzing data, making conclusions based on evidence, and comparing conclusions to the original hypothesis and prior knowledge. ▪ Students will be able to distinguish between qualitative and quantitative data. ▪ Students will be able to apply mathematics to analyze and support conclusions and models. ▪ Students will be able to identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions. ▪ Students will be able to apply established safety rules and guidelines in conducting scientific investigations inside and outside the classroom.
Comment: Grade 9-12, Standard I-B. The standard is a bit wordy. Perhaps the first part "The student will design, conduct, and evaluate a scientific investigation." is sufficient.				
GRADE 9– 12	I. HISTORY AND NATURE OF SCIENCE	C. Scientific Enterprise	The student will explain the relationship between science and technology and how both are used in our world.	▪ Students will be able to analyze an example of a way you use the scientific method in your daily life. ▪ Students will compare and contrast the goals and career opportunities of engineering/technology and science. ▪ Students will provide an example of a need/problem explained by science and solved by engineering/ technology. ▪ Students will describe the different scientific and engineering disciplines involved in a common household item. ▪ Students will provide an example of how technology facilitated a rapid advancement in science.
Comments: Grade 9-12, Standard I-C. Change benchmark 1 to passive voice: "Students will be able to analyze an example of the way that the scientific method can be used in daily life" I recommend eliminating the fourth benchmark ("Students will describe the different...") because it is imprecise (" involved in a common household item"?) and similar to the previous benchmark.				
GRADE 9–12	I. HISTORY AND NATURE OF SCIENCE	D. Historic Perspectives	The student will recognize the historical and cultural context of scientific endeavors and how they influence each other.	▪ Students will be able to trace the development of a scientific advancement, invention, or theory through time and its impact on society. ▪ Students will provide an example of a scientific advancement contributed by another civilization. ▪ Students will compare and contrast the differences between scientific theory and other bodies of knowledge, including cultural beliefs, and the importance of each in a science discussion.
Comments: Grade 9-12, Standard I-D. In the second benchmark, it is not clear what is meant by "another" civilization. I recommend eliminating benchmark 3, which seems a nod to the "Science as Social Knowledge" views of postmodernists and relativists. Cultural beliefs and scientific beliefs are like apples and oranges - they are not "different bodies of knowledge" that can be compared rationally in a scientific discussion.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	II. PHYSICAL SCIENCE	A. Structure of Matter	The student will understand the nature of matter including their forms, properties and interactions.	▪ Students will identify protons, neutrons, electrons as the major components of the atom, their mass relative to one another their arrangement, and their charge. ▪ Students will be able to explain the relationship of an element's position on the periodic table to its atomic number and mass. ▪ Students will compare and contrast the properties of an element and its isotopes and how isotopes can be used in research, medicine, and industry. ▪ Students will use the periodic table to identify regions, families, groups and periods, and to predict atomic size, number of bonding electrons and reactivity of elements. ▪ Students will be able to explain how atoms form compounds through ionic and covalent bonding. ▪ Students will compare and contrast the four states of matter in terms of structure and magnitude of intermolecular forces.

Comments:

This, and the sub-strand that follows, is a very weak treatment of chemistry at the high school level. The level expected here is more appropriate for grades 6-8. The standard is fine, as a general thought, but the benchmarks need to go much deeper. Rather than rewrite them, I will show samples of the level expected in many other states, which is substantially higher than what is proposed for Minnesota:

NEW MEXICO (2003)

Understand the structure and properties of matter, the characteristics of energy, and the interactions between matter and energy

- Classify matter in a variety of ways (e.g., element, compound, mixture; solid, liquid, gas; acidic, basic, neutral)
- Identify, measure, and use a variety of physical and chemical properties (e.g., electrical conductivity, density, viscosity, chemical reactivity, pH, melting point)
- Describe trends in properties (e.g., ionization energy or reactivity as a function of location on the periodic table, boiling point of organic liquids as a function of molecular weight)
- Understand that matter is made of atoms and that atoms are made of subatomic particles
- Understand atomic structure, including: most space occupied by electrons; nucleus made of protons and neutrons; isotopes of an element; masses of proton and neutron 2000 times greater than mass of electron; atom held together by proton-electron electrical forces
- Explain how electrons determine the properties of substances by: interactions between atoms through transferring or sharing valence electrons; ionic and covalent bonds; the ability of carbon to form a diverse array of organic structures
- Make predictions about elements using the periodic table (e.g., number of valence electrons, metallic character, reactivity, conductivity, type of bond between elements)
- Understand how the type and arrangement of atoms and their bonds determine macroscopic properties (e.g., boiling point, electrical conductivity, hardness of minerals).
- Know that states of matter (i.e., solid, liquid, gas) depend on the arrangement of atoms and molecules and on their freedom of motion.
- Know that some atomic nuclei can change, including: spontaneous decay; half-life of isotopes; fission; fusion (e.g. the sun); alpha, beta, and gamma radiation.

Grade	Strand	Sub-Strand	Standard	Benchmarks
INDIANA • Describe physical changes and properties of matter through sketches and descriptions of the involved materials. • Describe chemical changes and reactions using sketches and descriptions of the reactants and products • explain that chemical bonds between atoms in molecules, such as H2, CH4, NH3, C2H4, N2, Cl2, and many large biological molecules are covalent • Describe dynamic equilibrium • Perform calculations that demonstrate an understanding of the gas laws. Apply the gas laws to relations between pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases • Use kinetic molecular theory to explain changes in gas volumes, pressure, and temperature (Solve problems using pV=nRT). • Describe the possible subatomic particles within an atom or ion • Use an element's location in the Periodic Table to determine its number of valence electrons, and predict what stable ion or ions an element is likely to form in reacting with other specified elements. • Use the Periodic Table to compare attractions that atoms have for their electrons and explain periodic properties, such as atomic size, based on these attractions. • Infer and explain physical properties of substances, such as melting points, boiling points, and solubility, based on the strength of molecular attractions. • Describe the nature of ionic, covalent, and hydrogen bonds, and give examples of how they contribute to the formation of various types of compounds. • Describe that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship (E = hv)				
ALABAMA (Course of Study) 27. Explain the general concept of atoms. 28. Describe major ideas of natural philosophers and scientists in the historical development of concepts about atoms/elements. (Democritus, Empedocles, Dalton, Thomson, Rutherford, Bohr) 29. Describe particle motion in solids, liquids, and gases. 30. Relate the law of conservation of matter to the atomic theory. 31. Differentiate between homogeneous mixtures (solutions) and heterogeneous mixtures. 32. Relate the density of a substance to its mass and its volume. ALABAMA (High School Graduation Exam) II-3 Apply information from the periodic table and make predictions using the organization of the periodic table. Determine the number of protons, neutrons, electrons, and mass of an element using the periodic table. Use the periodic table to identify and locate metals, nonmetals, metalloids, and noble gases. Use data about the number of electrons in the outer electron shell of an atom, including simple dot diagrams, to determine its stability/reactivity and be able to predict ionic charge resulting from reactions. II-2 Relate particle motion to the states of matter (solids, liquids, and gases). Identify states of matter in terms of molecular (particle) movement, density, and kinetic energy associated with each phase/state of a given type of matter.				

Grade	Strand	Sub-Strand	Standard	Benchmarks

ILLINOIS (performance expectations, based on standard 12C, D)

Middle/Junior High School

- Model and describe the chemical and physical characteristics of matter (e.g., atoms, molecules, elements, compounds, mixtures)
- Explain interactions of energy with matter including changes of state and conservation of mass and energy

Early High School

- Analyze and explain the atomic and nuclear structure of matter
- Describe the effects of electromagnetic and nuclear forces including atomic and molecular bonding, capacitance and nuclear reactions

Late High School

- Analyze the properties of materials (e.g., mass, boiling point, melting point, hardness) in relation to their physical and/or chemical structures)
- Analyze reactions (e.g., nuclear reactions, burning of fuel, decomposition of waste) in natural and man-made energy systems.

CALIFORNIA

- Students know how to relate the position of an element in the periodic table to its atomic number and atomic mass.
- Students know how to use the periodic table to identify metals, semimetals, nonmetals,and halogens.
- Students know how to use the periodic table to identify alkali metals, alkaline earth metals and transition metals, trends in ionization energy, electronegativity,and the relative sizes of ions and atoms.
- Students know how to use the periodic table to determine the number of electrons available for bonding.
- Students know the nucleus of the atom is much smaller than the atom yet contains most of its mass.
- Students know how to use the periodic table to identify the lanthanide, actinide, and transactinide elements and know that the transuranium elements were synthesized and identified in laboratory experiments through the use of nuclear accelerators.
- Students know how to relate the position of an element in the periodic table to its quantum electron configuration and to its reactivity with other elements in the table.
- Students know the experimental basis for Thomson's discovery of the electron, Rutherford 's nuclear atom, Millikan's oil drop experiment, and Einstein 's explanation of the photoelectric effect.
- Students know the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom.
- Students know that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck 's relationship (E =hv).
- Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.
- Students know chemical bonds between atoms in molecules such as H 2 ,CH 4 ,NH 3 ,H 2 CCH 2 ,N 2 ,Cl 2 are covalent. ,and many large biological molecules
- Students know salt crystals,such as NaCl,are repeating patterns of positive and negative ions held together by electrostatic attraction.
- Students know the atoms and molecules in liquids move in a random pattern relative to one another because the intermolecular forces are too weak to hold the atoms or molecules in a solid form.
- Students know how to draw Lewis dot structures.
- Students know how to predict the shape of simple molecules and their polarity from Lewis dot structures.
- Students know how electronegativity and ionization energy relate to bond formation.
- Students know how to identify solids and liquids held together by van der Waals forces or hydrogen bonding and relate these forces to volatility and boiling/melting point temperatures.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	II. PHYSICAL SCIENCE	B. Chemical Reactions	The student will understand that the conservation of atoms in chemical reactions leads to the ability to calculate quantities of products and reactions in chemical changes of matter.	▪ Students will describe chemical reactions using words and symbolic equations. ▪ Students will observe, measure, and calculate quantities to demonstrate conservation of matter in chemical changes. ▪ Students will be able to explain how temperature, surface area, agitation, and catalysts influence the rate of reaction. ▪ Students will differentiate between complete and reversible reactions. ▪ Students will distinguish between a chemical reaction and a nuclear reaction.
Comments: Grades 9-12, Standard II-B. Again, this is a very weak treatment of high school chemistry, and I strongly recommend that the writing team look to other states, such as Indiana, Illinois, Alabama, New Mexico, and California. The course of study aligned to these proposed benchmarks will not develop a reasonable depth of understanding. I have not copied in the standards from other states to demonstrate this, but they are easily obtained and studied. This sub-strand in high school needs to be completely rethought by Minnesota chemists, and probably split into several standards.				
GRADE 9–12	II. PHYSICAL SCIENCE	C. Energy Transformations	The student will identify, analyze, and measure relationships with energy forms, transformations, and transfers.	▪ Students will know that potential energy in stored energy and is associated with gravitational or electrical force, mechanical position, or chemical composition. ▪ Students will differentiate between kinetic and potential energy and identify situations where kinetic energy is converted into potential energy and vise versa. ▪ Students will distinguish between current and static electricity. ▪ Students will distinguish between AC and DC current. ▪ Students will explain how electricity travels through circuits. ▪ Students will know that electricity in the movement of charged particles. ▪ Students will describe the production, storage, transmission of electricity. ▪ Students will know that photons behave as both particles and waves. ▪ Students will explain how the energy of the waves described the electromagnetic spectrum is used in research, medicine and industry. ▪ Students will be able to use the Law of Conservation of Energy to explain changes in energy in physical and chemical changes. ▪ Students will compare and contrast the amount of energy released through chemical reactions and nuclear fission and fusion. ▪ Students will describe the risks and benefits of fossil fuels, renewable sources, and nuclear power as sources of usable energy.
Comments: Grades 9-12, Standard II-C. This needs to be developed more carefully, and to much greater depth. The benchmarks should focus on elements such as the first and second laws of thermodynamics. At this point, understanding the relationship between work, heat, and total energy are much more important than "AC and DC current". In addition, these benchmarks seem to ignore the concept of entropy and the second law. Students are not expected to be able to use Ohm's law or calculate rate of energy dissipation in a resistive circuit. Students aren't expected to know about electrical induction with a magnet and coil, though perhaps they will be able to know a bit of superficial information about "production of electricity". In addition, the benchmarks in this standard tend to completely ignore chemical thermodynamics. This has a long way to go, and again, I recommend assembling the chemists and physicists in Minnesota for assistance, and looking to Indiana, Illinois, Alabama, New Mexico, and California Standards.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	II. PHYSICAL SCIENCE	D. Motion	The student will understand the nature of force and motion.	▪ Students will explain the relationship between force, mass, and acceleration. ▪ Students will know that an object that is not being subjected to a net force will continue to move at a constant speed and in a straight line (Inertia). ▪ Students will know that if more than one force acts on an object in a straight line, the forces will reinforce or cancel one another, depending on their direction and magnitude. ▪ Students will know that unbalanced forces will cause changes in the speed or direction of an object's motion. ▪ Students will use the concepts of inertia, force, velocity, and mass to describe the motion of an object. ▪ Students will describe the effect of friction and gravity on motion. ▪ Students will describe the relationship among energy, work and power both conceptually and quantitatively.
Comments: Grades 9-12, Standard II-D. This is a good start, but there is a substantial amount of material missing. Newton's first and second laws are presented, but where is Newton's third law? Where is an indication that students will be able to use the conservation of energy and conservation of momentum to solve problems in motion and collision? Where are the problems in circular motion?				
GRADE 9–12	II. PHYSICAL SCIENCE	E. Forces of Nature	Understand the forces of nature and their application in the real world.	▪ Students will be able to identify the gravity, electromagnetic, weak and strong nuclear forces as the four forces of nature. ▪ Students will be able to recognize that the nuclear forces that hold the nucleus of an atom together are usually stronger than the electric forces that would make it fly apart. ▪ Students will describe the electrical force that exists between any two charged objects and distinguish between attraction and repulsion between charged objects.
Comments: Grades 9-12, Standard II-E. The first and second benchmark are fairly pointless, seeing as the students are being given so little knowledge of the structure of the nucleus. The third benchmark might be helpful, if the description were made quantitative and used in problem solving. As it is, distinguishing between "attraction" and "repulsion" is an elementary school concept. The authors may want to reconsider the "Forces of Nature" sub-strand, and use it to fill in the tremendous gaps that exist in the physics course of study.				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	III. EARTH AND SPACE SCIENCE	A. Earth Structure and Processes	The student will understand how the interaction of the atmosphere, biosphere, lithosphere, hydrosphere and space has resulted in ongoing change of the Earth system over geologic time.	▪ Students will identify the internal and external sources of energy for the Earth. ▪ Students will demonstrate understanding of the laws of thermodynamics as they apply to the cycling of materials and transfer of energy in the Earth system. ▪ Students will give examples of how biological processes have played significant roles in determining the character of the atmosphere, biosphere and lithosphere over time. ▪ Students will be able to use the theory of plate tectonics to explain relationships among earthquakes, volcanoes, mountains, mid-oceanic ridges and deep-sea trenches. ▪ Students will be able to describe how glaciers, gravity, wind, temperature changes, waves, and rivers cause weathering and erosion. ▪ Students will describe the rock cycle and compare and contrast the processes responsible for the formation of igneous, sedimentary, and metamorphic rocks. ▪ Students will use evidence such as fossils, rock layers, ice caves, radiometric dating, and globally gathered data, to explain how Earth has changed or remained constant over short and long periods of time. ▪ Students will be able to apply an integrated understanding of chemistry, physics, and biology to the analysis of global change issues, such as ozone depletion, greenhouse warming and overpopulation. ▪ Students will be able to use globally gathered data to describe how Earth systems interact to create our climate and ecosystems.
GRADE 9–12	III. EARTH AND SPACE SCIENCE	B. The Water Cycle, Weather and Climate	The student will understand the relationships between the global atmospheric processes driven by energy from the sun, the Earth's tilt, rotation, revolution, the influence of land and water, and the impact of human affairs.	▪ Students will be able to explain how the transfer of energy and motions of the Earth all contribute to global atmospheric processes. ▪ Students will be able to trace cyclical movement of an element through the lithosphere, hydrosphere, atmosphere, and biosphere. ▪ Students will demonstrate the effect of the Earth's tilt, rotation, and revolution on the seasons, day length, and tides. ▪ Students will identify, investigate and predict the factors that influence the quality of water and how it can be reused, recycled and conserved. ▪ Students will be able to identify, analyze and evaluate the factors that may influence weather and climate, and describe both their short and long term effects on the environment. ▪ Students will discuss the impact of human activity and natural resource use on the Earth's climate. ▪ Students will be able to connect the biotic and abiotic factors that affect the evolution of the Earth's environment and structure. ▪ Students will explain how specific chemical reactions or reaction series have major implication for climate conditions and ecosystem change.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	III. EARTH AND SPACE SCIENCE	C. The Solar System	The student will connect the formation and characteristics of our solar system and its components to the conditions necessary for life.	▪ Students will be able to explain how the sun, earth, and solar system formed. ▪ Students will be able to compare and contrast the nature of the planets taking into account their composition, mass and distance from the sun. ▪ Students will be able to describe the remotely sensed evidence from current technology that has been used to understand the early history of the solar system. ▪ Students will be able to compare and contrast the environmental parameters that make life possible on Earth with conditions found on the other planets of our solar system.
GRADE 9–12	III. EARTH AND SPACE SCIENCE	D. The Universe	The student will understand that astronomical data reveals the structure, scale, and changes in the stars, galaxies, and universe over time.	▪ Students will recognize that stars, galaxy, and universe change over time. ▪ Students will recognize that the visible mass of the universe consists of billions of galaxies, each of which is a gravitationally bound cluster of billions of stars. ▪ Students will understand that stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. ▪ Students will be able to identify that the processes in stars that lead to the formation of other elements. ▪ Students will describe the evidence from current technologies that has been used to understand the early history of the universe.
GRADE 9–12	IV. LIFE SCIENCE	A. Cells	The student will comprehend that all living things are composed of cells and the life processes in a cell are based on molecular interactions.	▪ Students will be able to relate cellular structures and organelles to their functions. ▪ Students will be able to differentiate between prokaryotic and eukaryotic cells in terms of their structure and complexity. ▪ Students will compare and contrast the structures found in typical plant and animal cells. ▪ Students will be able to explain the role of the cell membrane as a highly selective barrier (diffusion, osmosis, active transport). ▪ Students will describe the role of enzymes as catalysts in metabolism and cellular synthesis of new molecules. ▪ Students will be able to differentiate between the processes of photosynthesis and respiration in terms of energy flow, reactants, and products. ▪ Students will describe how cell functions are regulated through intercellular and extra cellular signaling (hormones, neurotransmitters, proteins). ▪ Students will describe and compare the processes of mitosis and meiosis and their role in the cell cycle.

Grade	Strand	Sub-Strand	Standard	Benchmarks
Comments: Grades 9-12, Standard IV-A. Several of the benchmarks need to be made more specific. For example: • Students will be able to relate cellular structures (e.g. nucleus, nucleolus) and organelles (e.g. mitochondrion, chloroplast, endoplasmic reticulum, Golgi, lysosomes) to their functions. Otherwise, it isn't clear what depth of knowledge is expected. The benchmarks could be interpreted superficially if they are not explained with greater care.				
GRADE 9–12	IV. LIFE SCIENCE	B. Organisms	The student will classify, compare, and contrast the diversity of organisms on earth and their modes of accommodating the requirements for life.	▪ Students will relate the structure, complexity and organization of organisms (all organ systems) to their methods of obtaining, transforming, releasing, and eliminating the matter and energy used to sustain the organism. ▪ Students will be able to explain the development of multicellular organisms from a single cell through the regulation and expression of different genes. ▪ Students will recognize that organisms have innate and/or learned behavioral responses to internal and external stimuli, including the tropic responses in plants. ▪ Students will be able to identify significant adaptations that have allowed life to evolve from single-celled aquatic organisms to multicellular terrestrial organisms over a period of more than 3.5 billion years. ▪ Students will be able to use scientific evidence, including the fossil record, homologous structures, embryological development, or biochemical similarities, to classify organisms showing probable evolutionary relationships and common ancestry.
Comment: Grades 9-12, Standard IV-B. Benchmark 4 ("Students will be able to identify significant ...") should be eliminated - it is better covered in sub-strand E, benchmark 4. Alternatively, it could represent a look at the adaptations in present day organisms, from single-cell through multicellular organisms.				
GRADE 9–12	IV. LIFE SCIENCE	C. Diversity and Interdependence or Life	The student will describe how the environment and interactions between organisms can affect the number of species and the diversity of species in an ecosystem.	▪ Students will be able to describe the factors related to matter and energy in an ecosystem that influence fluctuations in population size and determine the carrying capacity of a population. ▪ Students will be able to explain how adaptations of species and co-evolution with other species are related to success in an ecosystem. ▪ Students will identify the types of symbiotic relationships (mutualism, commensalism, parasitism) that occur in a stable ecosystem. ▪ Students will predict and analyze how a change in an ecosystem, resulting from natural causes, changes in climate, human activity, or introduction of invasive species, can affect the number of organisms in a population and the biodiversity of species in the ecosystem.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	IV. LIFE SCIENCE	D. Heredity	The student will explain how inherited characteristics are encoded by genes.	▪ Students will be able to explain that the instructions for the characteristics of all organisms are carried in nucleic acids (DNA and RNA). ▪ Students will be able to define the relationship between DNA, genes, and chromosomes. ▪ Students will describe the structure and function of DNA and distinguish between replication, transcription, and translation. ▪ Students will know that different species of multicellular organisms have a characteristic diploid number chromosomes, and that in typical humans there are 22 autosomal pairs and two sex chromosomes (XX for female and XY for male). ▪ Students will describe how genetic information is transmitted from parents to offspring through the process of meiosis and fertilization as they relate to chromosome recombination and sexual reproduction. ▪ Students will be able to use Mendel's laws of segregation and independent assortment and a Punnett Square to determine the genotype and phenotype of a monohybrid crosses. ▪ Students will differentiate between dominant, recessive, co- dominant, incompletely dominant, polygenic, and sex-linked traits. ▪ Students will be able to explain how somatic and germ-line mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and/or its offspring. ▪ Students will determine the factors that affect the rate of mutations, including, but not limited to, ionizing radiation and chemicals. ▪ Students will recognize that biochemical analytical techniques allow for sophisticated analysis with applications such as forensic science, genetic engineering of plants, and medical applications and their societal impacts.
Comments: Grades 9-12, Standard IV-D. The first and third benchmarks need to be increased in depth, so that students understand the roles of mRNA and tRNA in protein synthesis. It is not enough for students to "distinguish" between replication, transcription and translation - they need to understand these key processes. Without this foundation, it will not be possible for students to understand mutations that lead to changes in proteins (benchmark 8). It will also be difficult for them to understand gene expression and cell specialization. These points are much more important as a foundation than distinguishing between, for example, co-dominance and incomplete dominance (in benchmark seven).				

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	IV. LIFE SCIENCE	E. Biological Populations Change Over Time	The student will explain how evolution provides a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.	▪ Students will understand that species change over time and the term biological evolution is used to describe this process. ▪ Students will describe how natural selection, the mechanism of biological evolution, causes the differential survival of groups of organisms as a consequence of: a. the potential for a species to increase its numbers; b. the genetic variability of offspring due to mutation and recombination of genes; c. a finite supply of the resources required for life; d. the ensuing selection based on environmental factors of those offspring better able to survive and produce reproductively successful offspring. ▪ Students will be able to predict the success or failure of a population of organisms over time based on genetic variability of offspring, the ability to reproduce, and the exposure to changing environmental factors. ▪ Students will be able to describe how genetic variation between populations is due to different selective pressures acting on each population, which can lead to speciation/a new species. ▪ Students will recognize that a great amount of time, approximately 3.5 billion years, is necessary to explain the variation of species that has produced the great diversity of life currently present on earth and found in the fossil record.
GRADE 9–12	IV. LIFE SCIENCE	F. Flow of Matter and Energy	The student will describe and explain the cycling of matter and flow of energy through an ecosystem's living and non-living components.	▪ Students will be able to explain the relationship between abiotic and biotic components of an ecosystem in terms of cycling of water, carbon, oxygen, and nitrogen. ▪ Students will know that all matter tends to become more disorganized and that living systems require a continuous input of energy in order to maintain their chemical and physical organizations and prevent death. ▪ Students will identify that the primary source of energy for life and fossil fuels is derived from the sun, and explain how sunlight energy is transformed into chemical energy by photosynthesis in organisms. ▪ Students will identify and distinguish producers, consumers, and decomposers, and explain the transfer of energy through the trophic levels. ▪ Students will describe how respiration releases chemical energy by the breakdown of molecules and store the energy. ▪ Students will understand that energy flows through different levels of organization of living systems (cells to communities) and between living systems and the physical environment as chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy.

Grade	Strand	Sub-Strand	Standard	Benchmarks
GRADE 9–12	IV. LIFE SCIENCE	G. Human Organism	The student will relate the structure and function of human organ systems to the ability to maintain a stable internal environment (homeostasis) despite changes in the outside environment.	▪ Students will explain how major organ systems in humans have functional subunits with specific anatomy that perform the function of that organ system. ▪ Students will understand and describe the basic anatomy and physiology of the nervous system and sense organs. ▪ Students will be able to describe how the function of individual systems within humans is integrated to maintain a homeostatic balance in the body. ▪ Students will be able to illustrate how feedback loops in the nervous and endocrine system regulate conditions in the body. ▪ Students will realize that behavioral biology has implications for humans since it provides links to psychology, sociology and anthropology.