

SEQUENCED BENCHMARKS FOR K–8 SCIENCE

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TABLE OF CONTENTS

Introduction	1
Purpose.....	1
Source Documents	1
Method	2
How this Document Can Be Used	3
Sequenced Benchmarks	5
Earth and Space Science	
1. Characteristics of the Earth System	6
2. Earth’s History	7
3. Earth’s Surface Features	8
4. Energy in the Earth System.....	9
5. Motion of the Earth and Moon.....	10
6. Rocks, Minerals, and Soil	11
7. Seasons, Weather, and Climate.....	12
8. The Solar System	13
9. The Sun and Other Stars	14
10. The Universe	15
11. Water in the Earth System	16
Life Science	
12. Characteristics of Organisms	17
13. Diversity and Unity among Organisms.....	18
14. Interdependence of Organisms	19
15. Populations and Ecosystems	20
16. Relationships between Organisms and the Environment	21
17. Structure and Function in Organisms	22
Physical Science	
18. Chemical Reactions	23
19. Conservation of Matter and Energy.....	24
20. Electricity and Magnetism	25
21. Energy Transfer and Entropy.....	26
22. Forces and Motion	27
23. Forms of Energy (Heat Energy)	28
24. Forms of Energy (Light Energy).....	29
25. Position and Motion.....	30
26. Properties of Substances	31
Bibliography	32

INTRODUCTION

PURPOSE

At the beginning of the standards movement in the early to mid 1990s, most states described standards content in broad grade bands of benchmarks or objectives, such as K–4, 5–8, and 9–12. As states have revised their standards, they have made them somewhat more specific, for example, K–2, 3–5, and 6–8. Some states have taken this process a step further by describing content for each level from kindergarten through grade 8. A significant number of states, however, still do not provide such grade-by-grade distinctions in standards. Although this lack of specificity provides districts with some freedom to define the local curriculum, for many districts it presents an immediate problem. In order to implement standards, districts must find a way to translate these grade-range standards into meaningful benchmarks or objectives for day-to-day schooling at specific grades.

Unfortunately, there has been little guidance available to districts as they undertake this process. Although documents produced by national subject-area organizations might be considered the highest authority in this regard, none provides grade-by-grade recommendations. It seems likely that these organizations were deterred by the lack of research supporting placement of content at specific grade levels. In addition, many organizations avoid the assignment of content to a grade because it is likely to be seen as overly prescriptive. Yet, the problem for a school district remains. Content must be assigned to a grade because it must be taught at a grade.

Although there is inadequate research support — and this will likely always be the case — to assign specific content definitively to a specific grade, there is information available about the sequence in which content should be presented in the curriculum. The American Association for the Advancement of Science (AAAS) has co-published *Atlas of Science Literacy* (2001) with the National Science Teachers Association. The *Atlas* comprises a series of conceptual strand maps that present students' growth in understanding, showing how the ideas and skills that students learn in different grades and topics depend on and support one another. The strand maps are based on an analysis of the content described in *Benchmarks for Science Literacy* (AAAS, 1993).

The current report provides a somewhat different, though related approach. Like the *Atlas*, this report organizes benchmarks by topic. Rather than proposing a sequence of content organization based upon an analysis of each benchmark, this report describes the sequence of content that consistently appears among a set of highly rated state standards. The report also includes information on the specific grades at which the content was placed within these documents. Simpler in scope than the *Atlas*, this report should nonetheless provide useful information for curriculum directors and others who must make choices regarding grade assignments for science content.

SOURCE DOCUMENTS

Two evaluation reports were used to help select the state documents used for the process of identifying the appropriate articulation of science content. One report was *Making Standards Matter* (2001), by the American Federation of Teachers, which includes ratings of the state standards in terms of specificity and clarity. Another perspective on state standards was published by the Fordham Foundation in the report *The State of State Standards in Science*

(Lerner, 2000). Four of the state documents that were highly rated in both reports *and* that identify objectives at each grade, kindergarten through 8th grade, were selected as source documents:

- California’s Science Content Standards Grades K-12* (1998)
- Ohio’s Model Competency-Based Science Program* (Draft 2001)
- South Carolina Science Curriculum Standards: K–8 Science Standards* (2000)
- South Dakota Science Standards* (June 1999)

METHOD

In order to track science content across these state documents, each of which varies in level of specificity and manner of content description, a uniform set of benchmarks was required for comparison. McREL’s online standards database was used for this purpose. The database, the online equivalent of *Content Knowledge: A Compendium of Standards and Benchmarks for K–12 Education* (3rd ed.) (Kendall & Marzano, 2000), provides a synthesis of 137 standards documents representing 14 content areas.

In addition to a comparison set of benchmarks, it also was necessary to use a set of topics to organize this information. A topic is a level of organization that is more specific than a standard and organizes a set of benchmarks or objectives. Several topics are commonly found within a standard, and each topic organizes two or more benchmarks. The topic list used for this analysis was one developed at McREL for the online standards database (for a description of the process of topic development and samples in mathematics and language arts, see Kendall, 2000). The list of topics, organized by sub-discipline, is presented in Exhibit 1.

Exhibit 1. Summary of Topics

<p>Earth and Space Science</p> <ol style="list-style-type: none"> 1. Characteristics of the Earth System 2. Earth’s History 3. Earth’s Surface Features 4. Energy in the Earth System 5. Motion of the Earth and Moon 6. Rocks, Minerals, and Soil 7. Seasons, Weather, and Climate 8. The Solar System 9. The Sun and Other Stars 10. The Universe 11. Water in the Earth System 	<p>Life Science</p> <ol style="list-style-type: none"> 12. Characteristics of Organisms 13. Diversity and Unity among Organisms 14. Interdependence of Organisms 15. Populations and Ecosystems 16. Relationships between Organisms and the Environment 17. Structure and Function in Organisms <p>Physical Science</p> <ol style="list-style-type: none"> 18. Chemical Reactions 19. Conservation of Matter and Energy 20. Electricity and Magnetism 21. Energy Transfer and Entropy 22. Forces and Motion 23. Forms of Energy (Heat Energy) 24. Forms of Energy (Light Energy) 25. Position and Motion 26. Properties of Substances
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The articulation of benchmarks for each topic in this guide was developed entirely from the source documents specified above. Each document was reviewed for any *sequence information* it provided by topic. Sequence information is defined as the presence of a concept or skill in a grade that is topically related to a concept or skill in a higher or lower grade. That is, in any given document, two or more topic-related concepts must appear separated by at least one grade to be considered informative in the development of articulated content. Simply put, if two benchmarks addressing a given topic appeared in the same grade, it was inferred that the authors of the document did not consider the difference between content to be significant enough that the benchmark or objective should be addressed in separate grades.

If and when the presence of sequenced content was established in any one document, the same relative sequence — that is, the sequence of earlier to later grade — had to be supported by at least one additional document in order to be considered useful relative to the articulation of content within the topic. The sequence of content also could not appear reversed in any other document. Thus, if an identified sequence showed concept A in an early grade and concept B in a later one in two separate documents, but in the reverse grade sequence in a third document, then the articulation was considered not established.

Once an articulation was established by sufficient evidence from the standards documents, the range of articulation was assigned based on grade information. For example, suppose one document placed a concept under a topic at grade 3 and the related concept at grade 5, and a second document placed the same concept under grade 4 and the related concept at grade 6. In such a case, the first concept would be identified with the 3–5 grade range; the second, with 4–6. This means that, although both concepts could conceivably be addressed in grade 4 or both in grade 5, evidence supports the placement of the content in differing grades and somewhere within the specified grade ranges.

The product of this analysis is presented in 26 topic sequences, each of which represents the articulation of a topic that was supported by the evidence from state standards documents. There are 25 topics addressed (one topic – Forms of Energy – has more than one articulation of content). It should be noted that there are additional benchmarks appropriate for any given topic as well as those that appear in any given topic sequence. Each sequence lists only those benchmarks whose articulation could be supported by the documents. Similarly, there are many topics that are not articulated in this study because there was inadequate support. Of the 52 topics identified for the science standards in McREL’s standards database, approximately 50 percent could not be articulated. However, the topics in this report represent the sequencing of 91 unique benchmarks; some benchmarks appear in more than one sequence because they were appropriate for more than one topic.

HOW THIS DOCUMENT CAN BE USED

This document should prove useful for those districts and schools that seek to assign their state’s grade-range content to specific grades for instruction. It is likely that the topics in the sequences that follow are addressed in nearly every state’s science standards. Reviewing each topic in turn, users should compare the content to determine if it is addressed in their state’s standards document. If it is, the treatment and grade-range placement of content in the state document should be mapped against the topic in each sequence. This process will help users determine not

only whether the significant aspects of the given topic are fully addressed in the state standards, but also how well the grade-range placement accords with the standards documents used in this analysis. Having completed this rough mapping of content in a topic sequence to the state standards, users should consider the grades at which the same or similar content has been placed in the other state standards documents — information that is available as a footnote to each benchmark. This should at least help to narrow the grades for assignment, and perhaps make clear at what grade the benchmark is commonly taught.

Users of this document will want to consider the impact that grade placement might have on ensuring that standards continue to be aligned with their state standards, however. For example, if differing source documents indicate that given content could be placed at either grade 4 or 5, and the user's own state standards place very similar content at the K–4 grade band, then grade 4 would be the stronger choice. Similarly, any information available about the assessment of science content should be part of the decision-making process. If science content is assessed in the fall of grade 6, for example, the appropriate content should be placed in the prior grade so that students will have an opportunity to learn the material before being tested on it.

Once any one benchmark is assigned a grade, the user then should consider for placement those benchmarks that are positioned above or below the given benchmark in the topic sequence — that is, those that precede and follow it — to determine whether they should be placed in the grade before or after the grade level of the benchmark. In similar fashion, the remaining topics should be reviewed for information that is available from the topic sequences in the course of making grade placement decisions.

It is difficult to imagine the research that could support the idea that specific content should be part of instruction in one particular grade as opposed to the grades just preceding or following it. There does appear to be some agreement, however, that certain concepts and skills can be articulated in a progression of understanding that helps students learn. This study identifies the articulation of content as it was found expressed in a number of highly rated state standards documents. It also includes information about the grade levels at which that content appears. It is hoped that educators who seek to make decisions about grade placement of content will find this information useful.

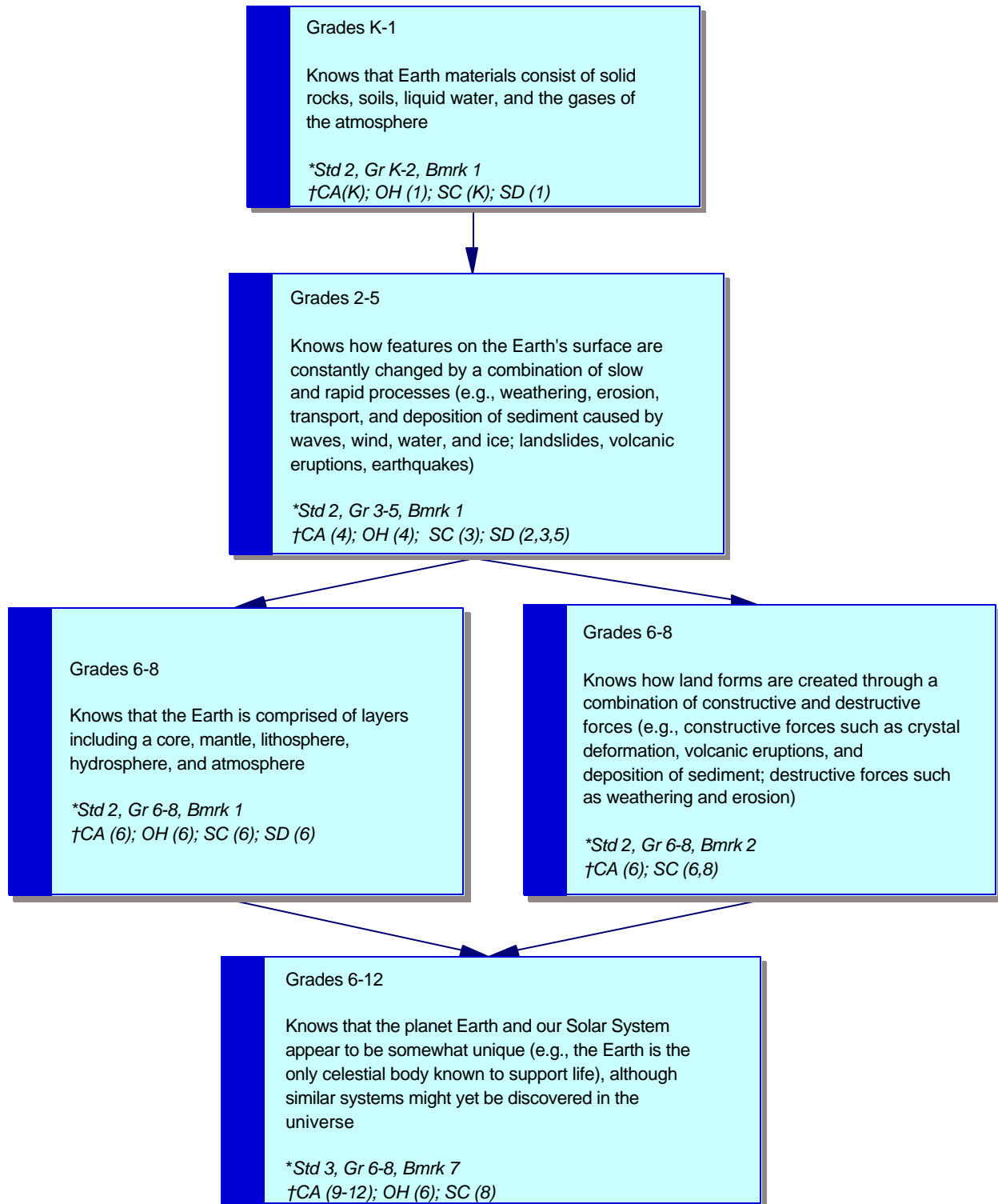
SEQUENCED BENCHMARKS

For each of the 26 science topics analyzed in this section, the layout of the benchmark boxes indicates the sequence in which content should be presented in the curriculum. Note that at some grade levels two benchmarks are presented. They are presented at the same level to indicate that there is insufficient information to indicate that one benchmark should be taught before the other. Occasionally benchmark ranges overlap. For example, in the topic area of “Characteristics of the Earth System,” the 6–12 benchmark follows the 6–8 benchmarks to indicate that it should be taught after the two 6–8 benchmarks. All three of these benchmarks could, of course, be taught at any grade from 6 through 8 — the grades they have in common. If they were, we recommend that the 6–12 benchmark be taught subsequent to the other two as indicated by its placement below the two 6–8 benchmarks.

For each benchmark in a sequence, the range of grades in which this content was found in the source documents is noted (e.g., K–1); the note preceded by the † symbol indicates the specific grades and states in which the content was found. In a number of cases, the content was found in more than one grade in a given state standards document. In this case, each grade is listed, separated by a comma. Also following each benchmark statement, in italics, is the standard number, grade range, and order in which the benchmark appears in McREL’s standards database.

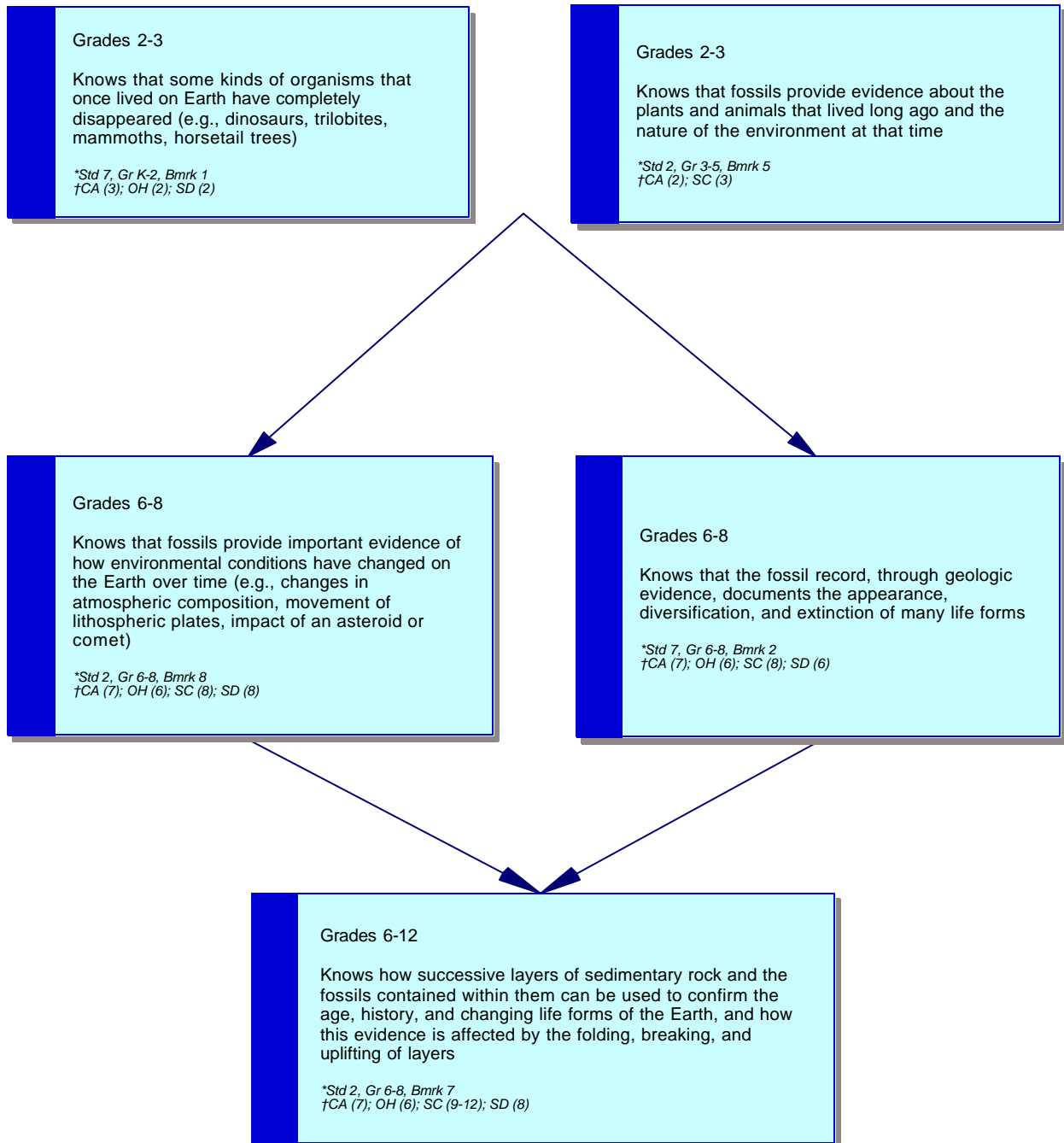
It should be noted that for some topics the grade range noted extends into high school. This is only the case when one of the source documents identifies the high school range as appropriate for the content addressed. In any event, none of the benchmarks articulated in this report appears later than 8th grade in the McREL standards database.

TOPIC 1: CHARACTERISTICS OF THE EARTH SYSTEM



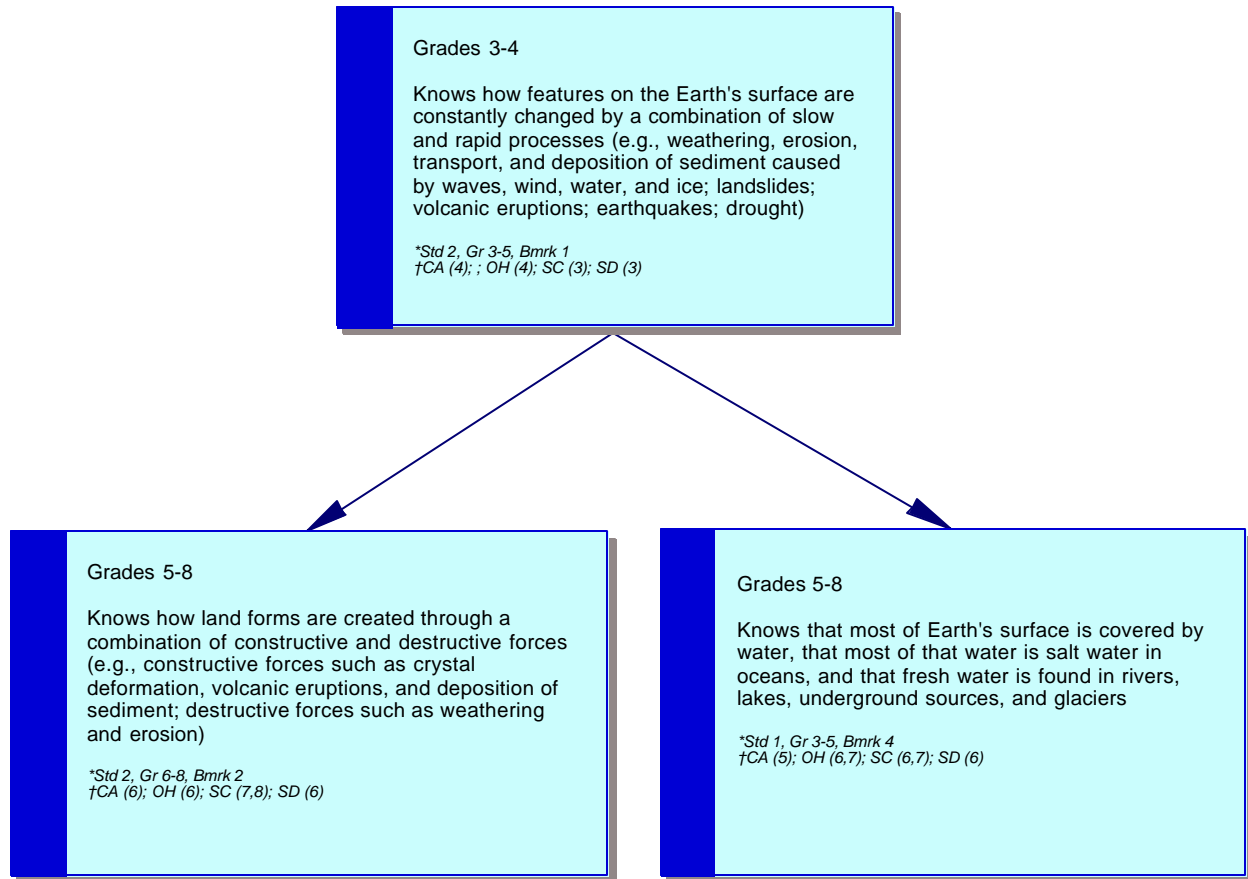
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 2: EARTH'S HISTORY



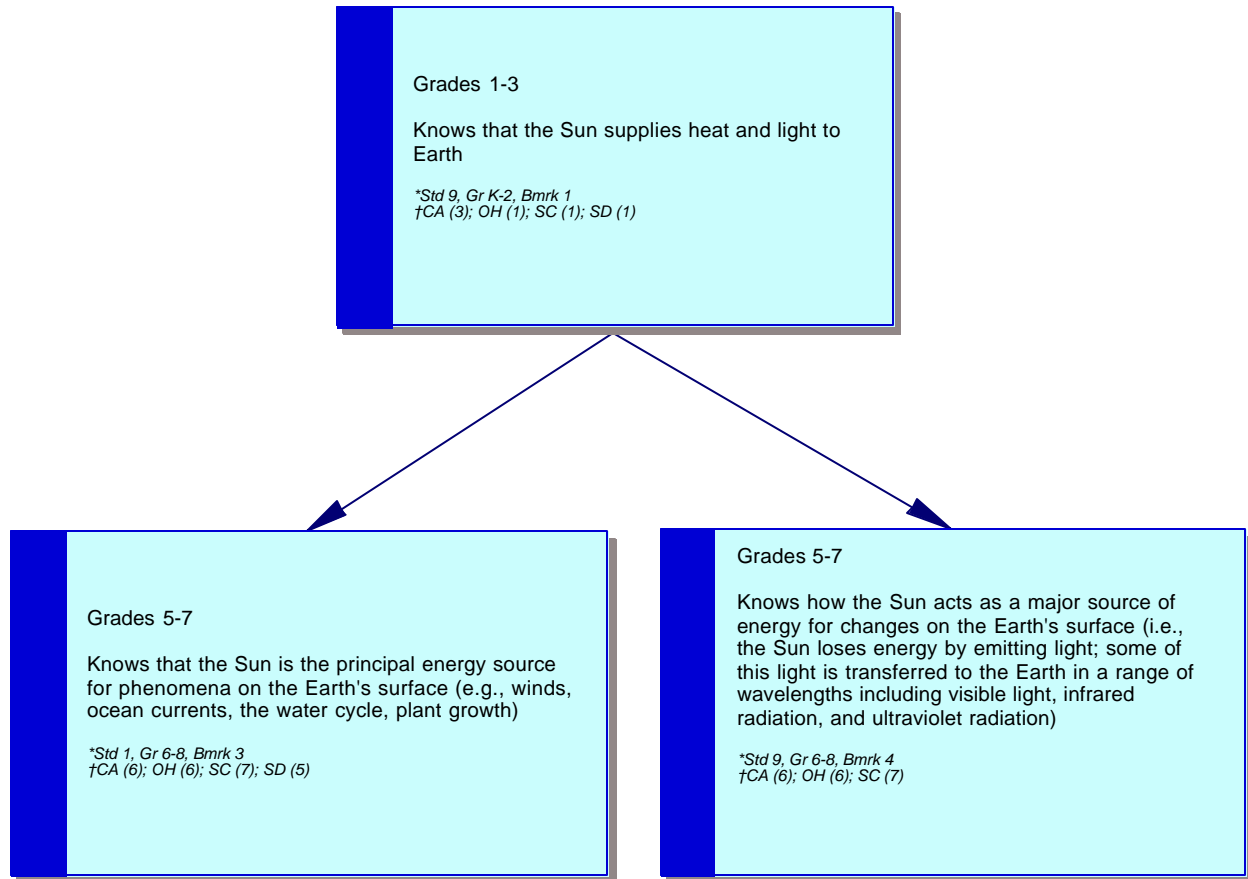
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 3: EARTH'S SURFACE FEATURES



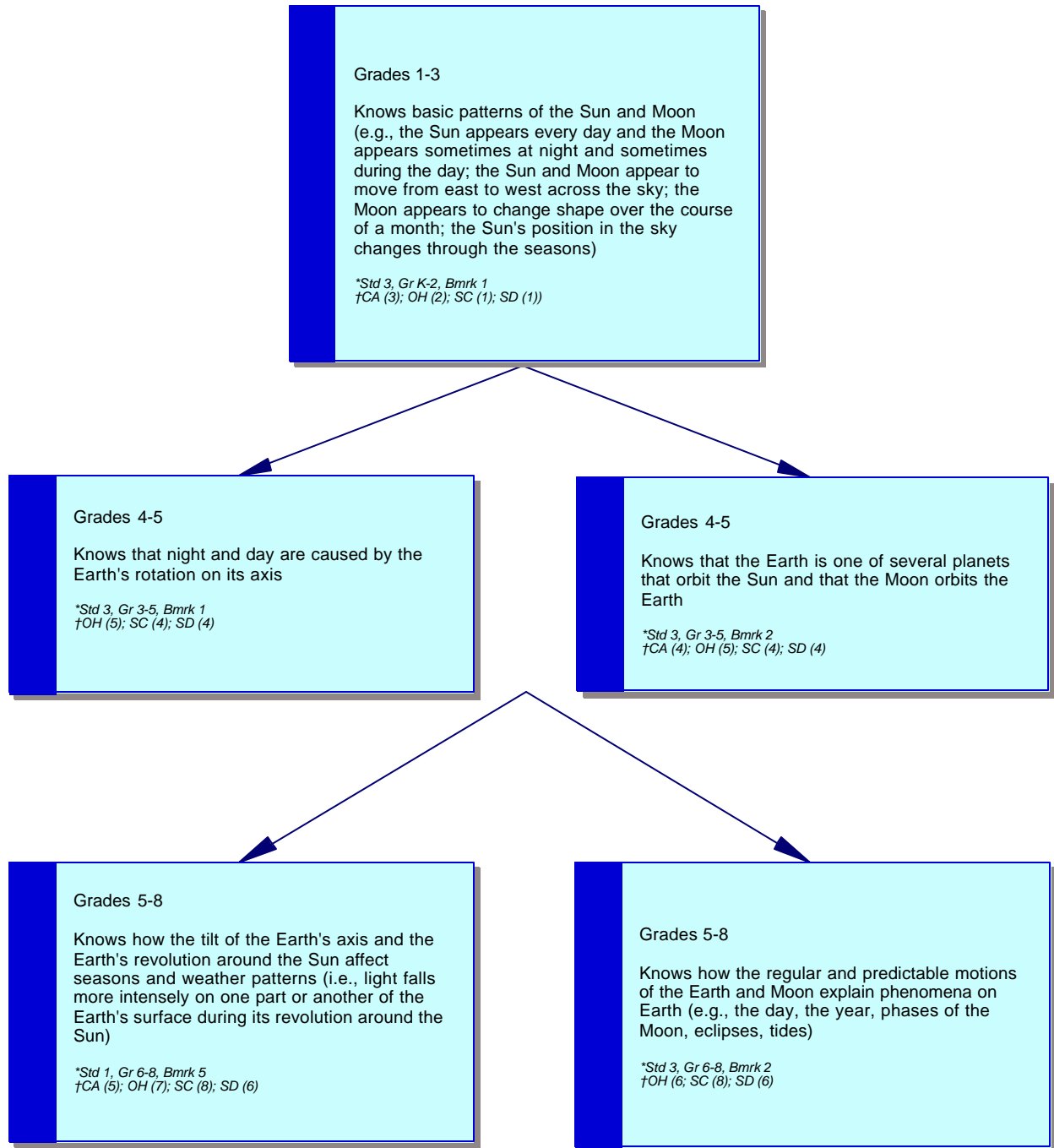
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
*†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing**

TOPIC 4: ENERGY IN THE EARTH SYSTEM



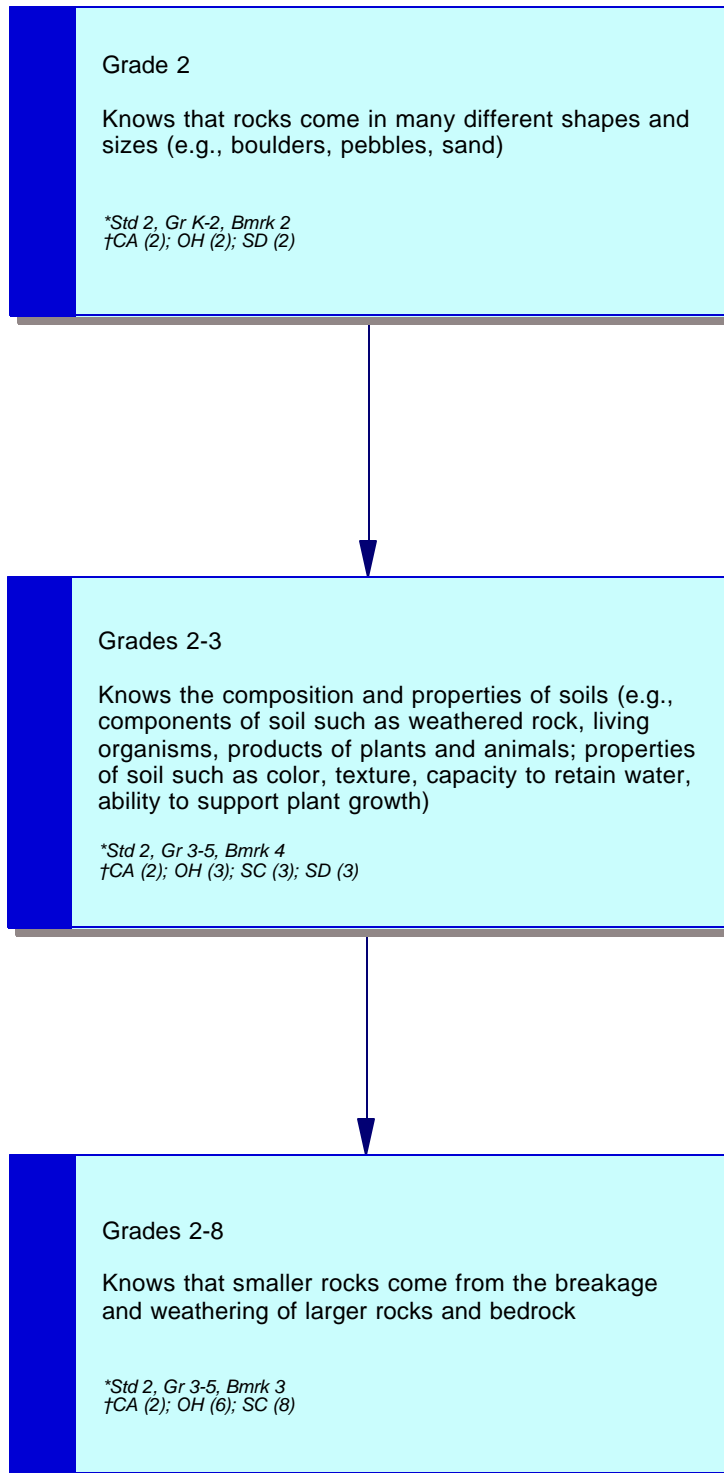
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 5: MOTION OF THE EARTH AND MOON



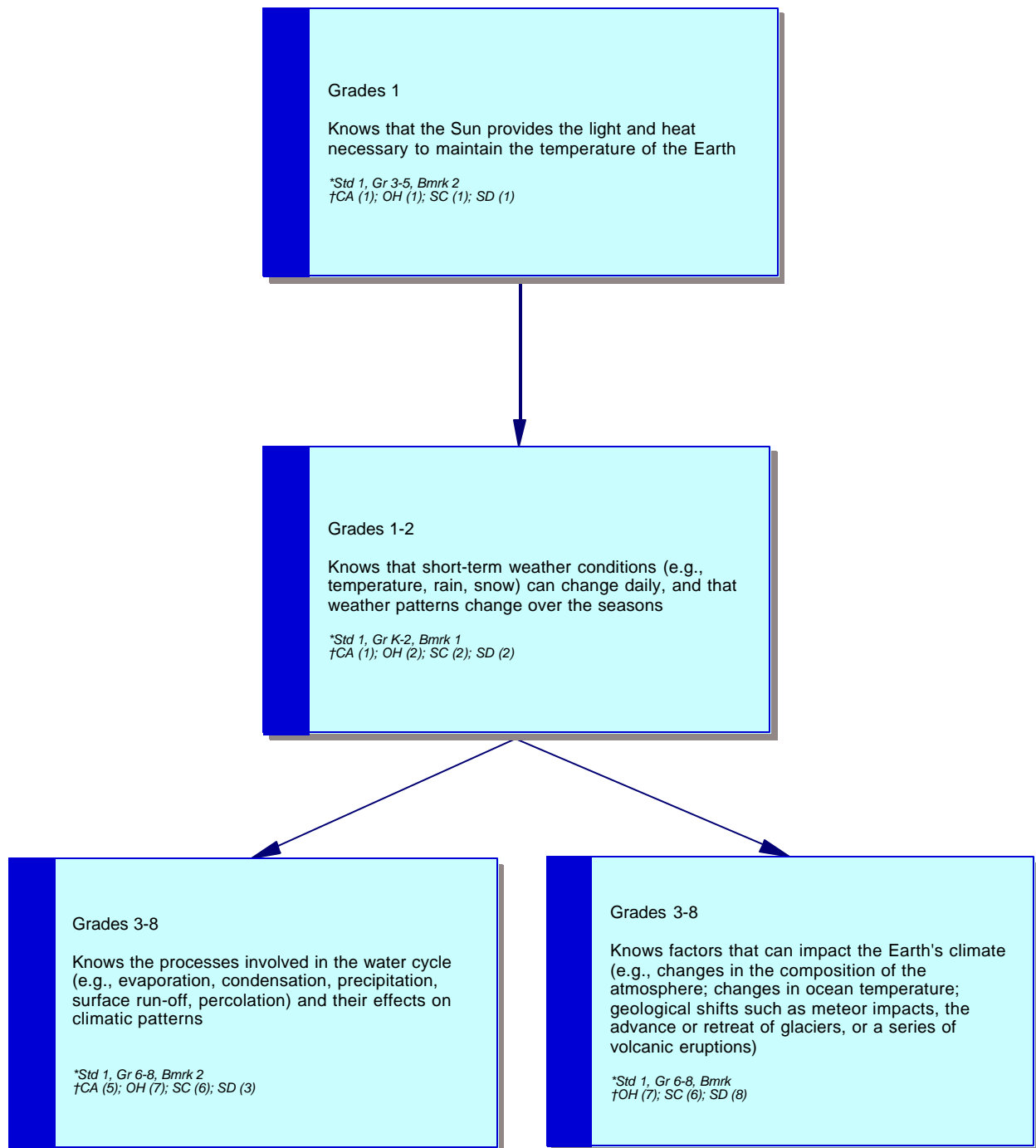
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 6: ROCKS, MINERALS AND SOIL



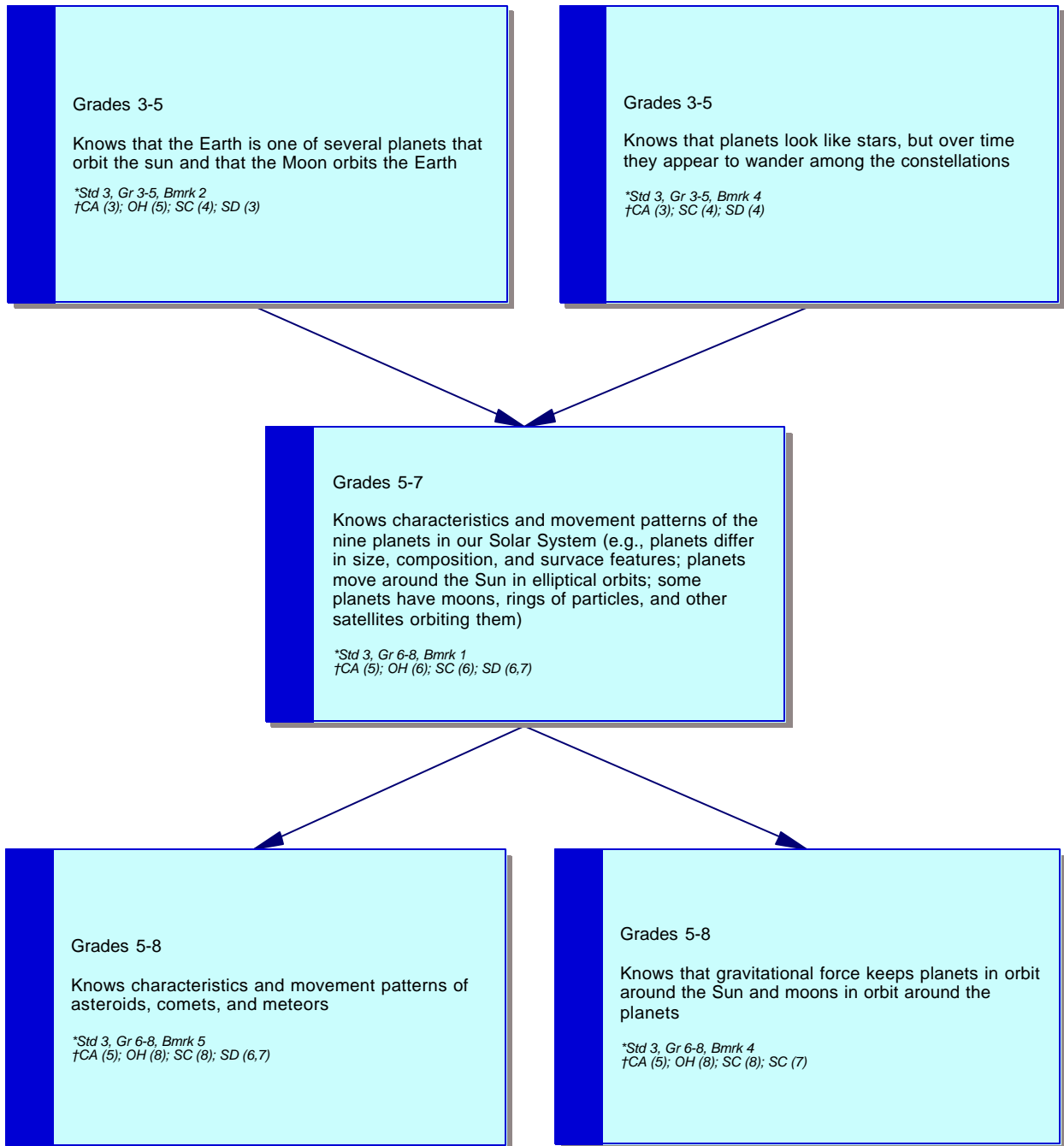
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 7: SEASONS, WEATHER, AND CLIMATE



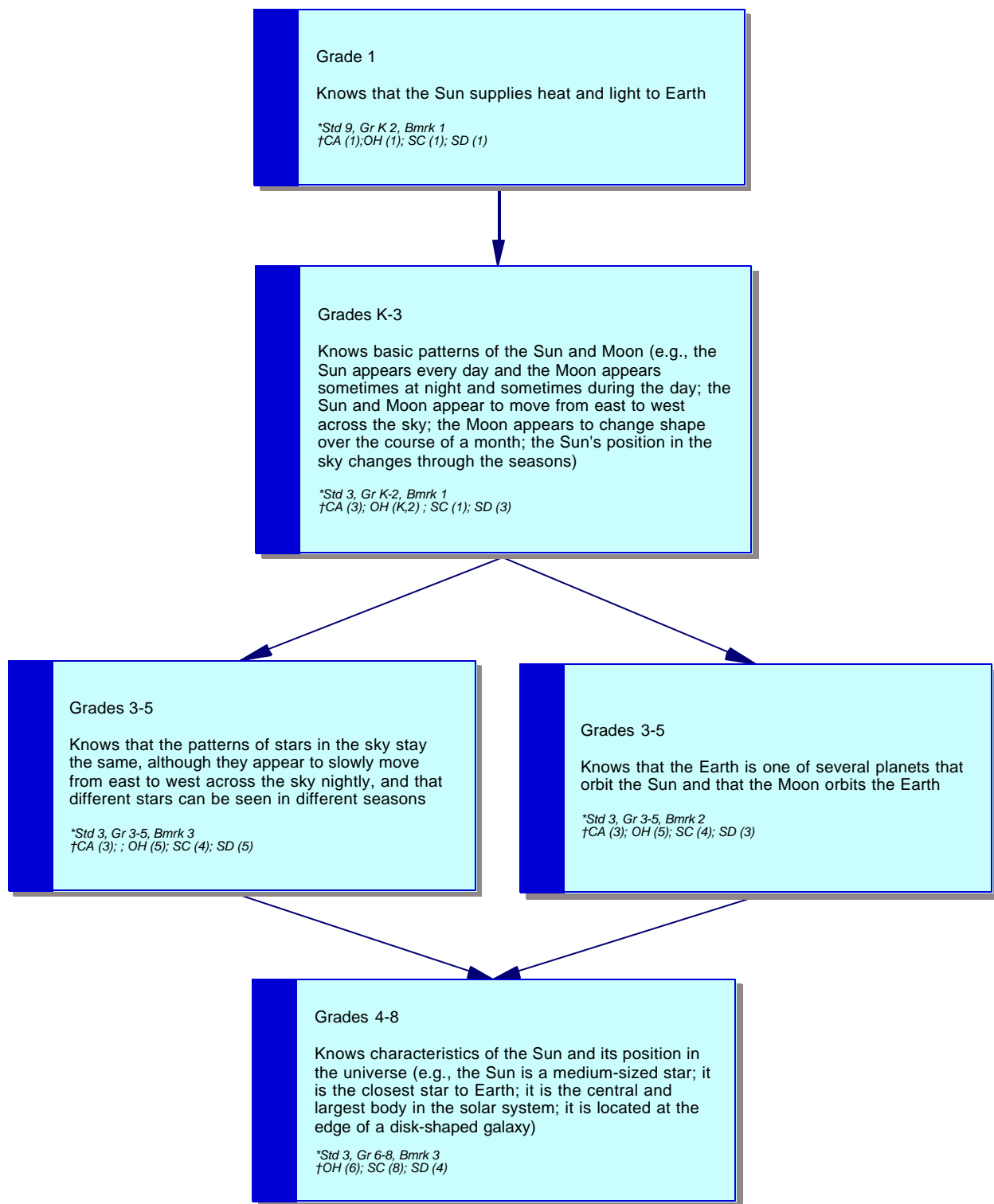
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 8: THE SOLAR SYSTEM



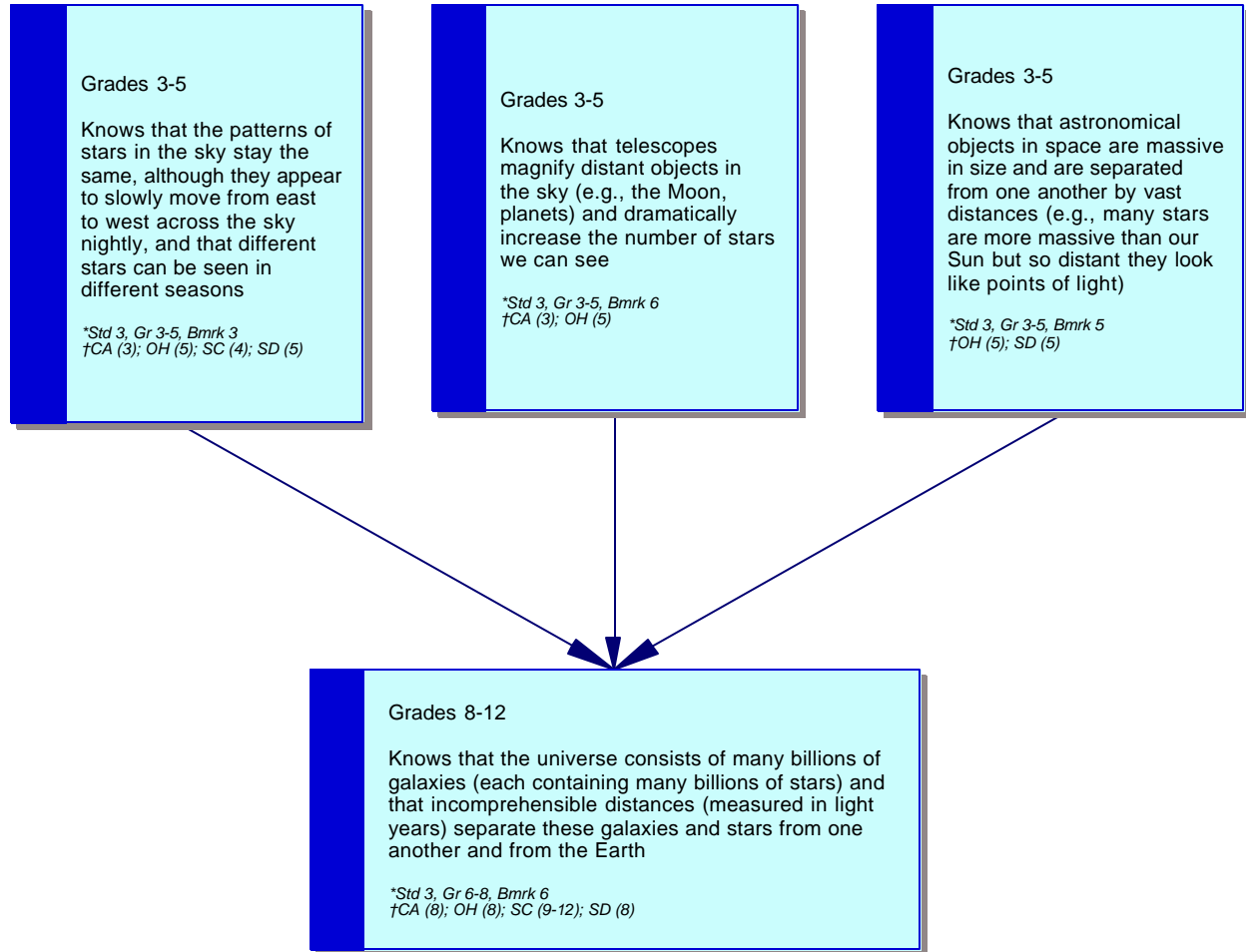
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 9: THE SUN AND OTHER STARS



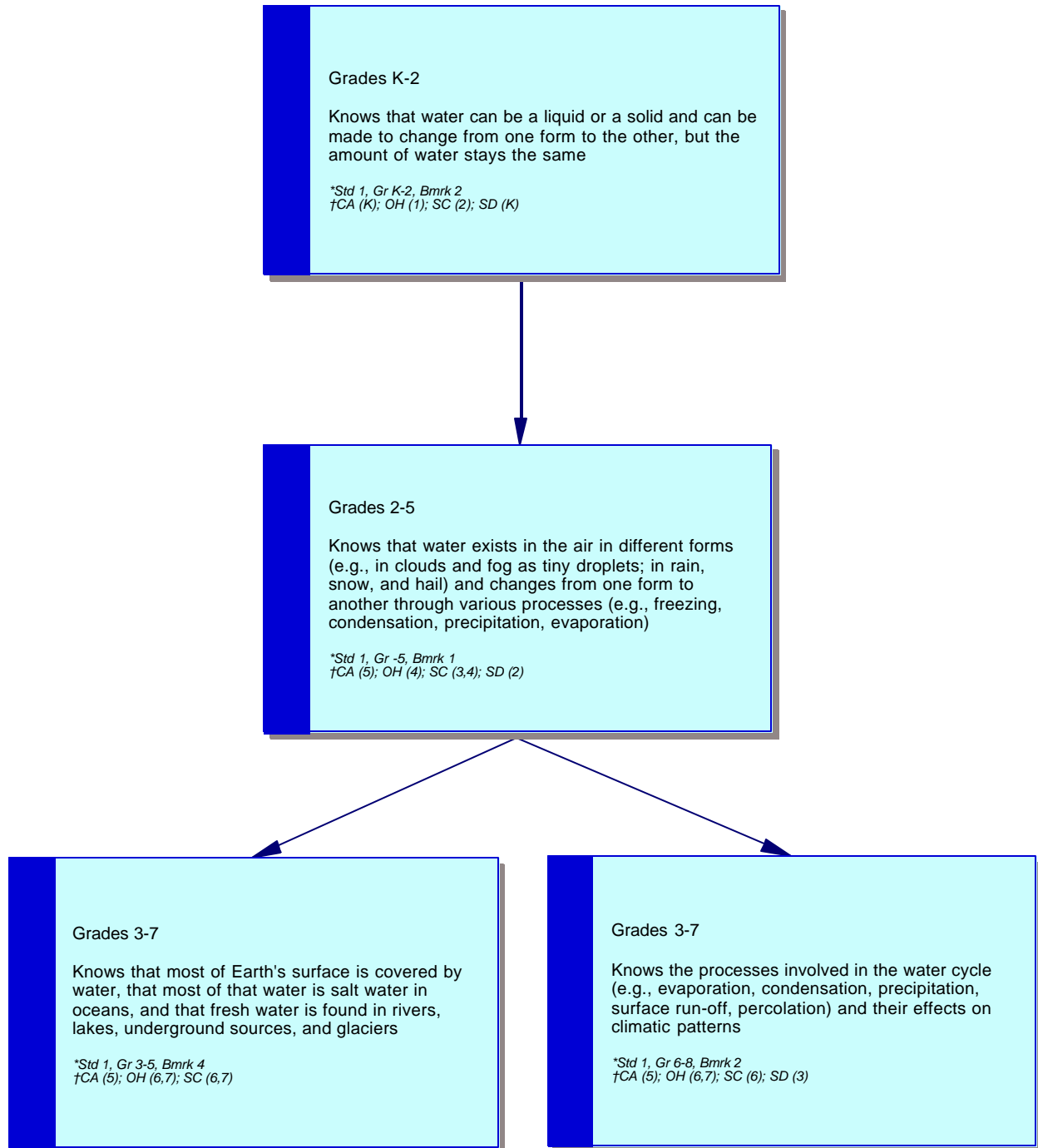
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 10: THE UNIVERSE



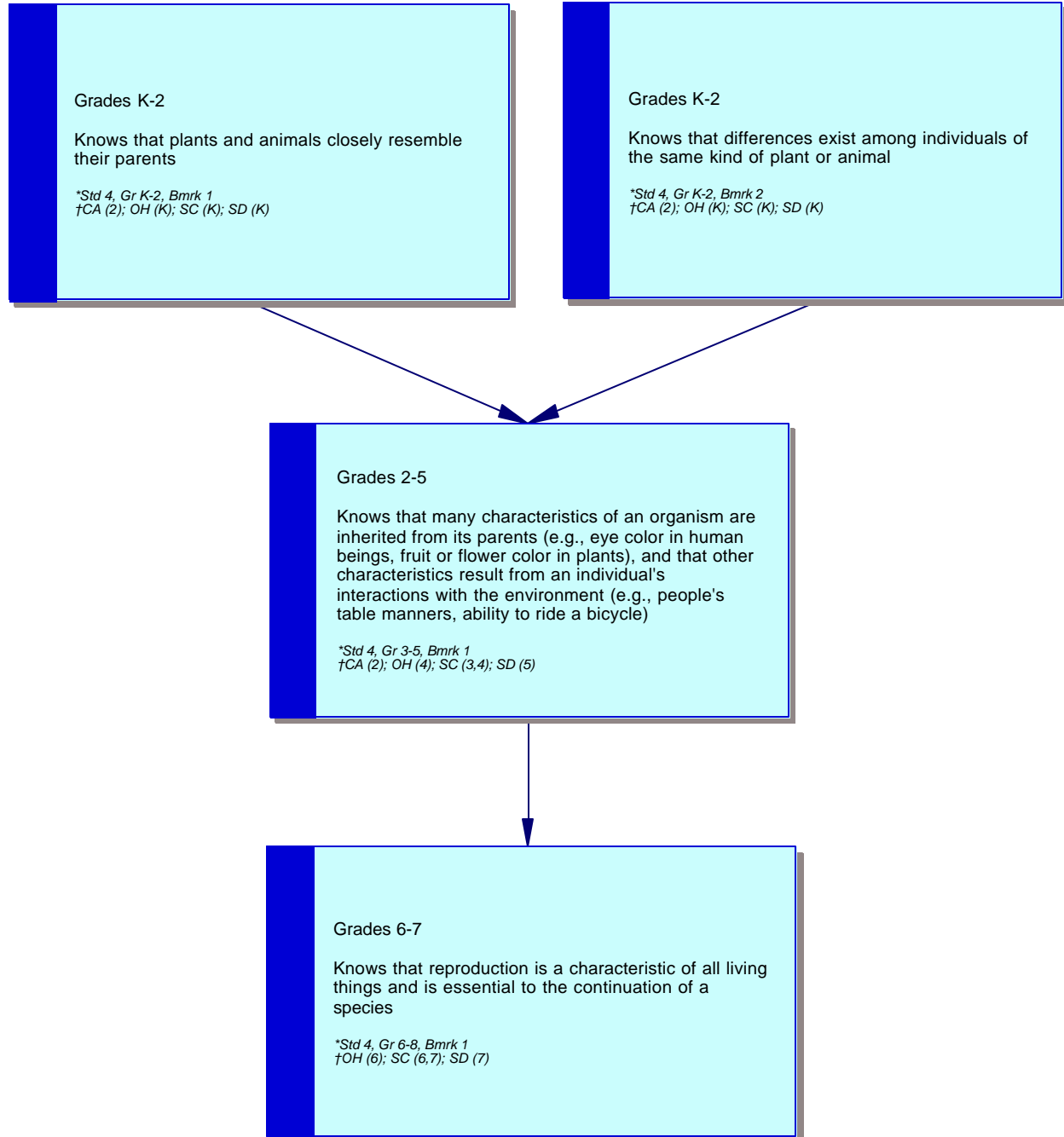
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 11: WATER IN THE EARTH SYSTEM



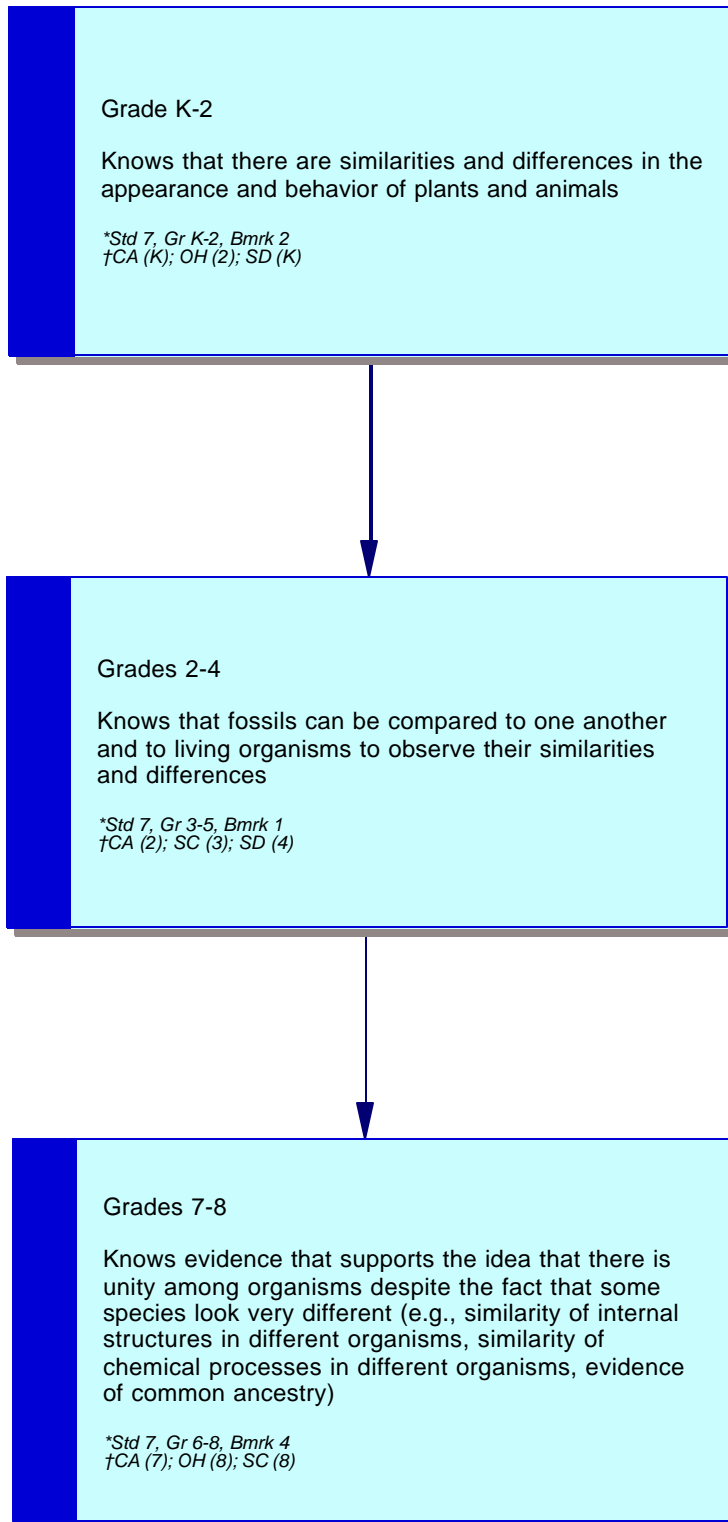
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
*†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing**

TOPIC 12: CHARACTERISTICS OF ORGANISMS



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 13: DIVERSITY AND UNITY AMONG ORGANISMS



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 14: INTERDEPENDENCE OF ORGANISMS

Grade K-4

Knows the organization of simple food chains and food webs (e.g., green plants make their own food with sunlight, water, and air; some animals eat the plants; some animals eat the animals that eat the plants)

**Std 6, Gr 3-5, Bmrk 1*
†CA (4); OH (3); SC (2); SD (K)



Grades 4-5

Knows ways in which organisms interact and depend on one another through food chains and food webs in an ecosystem (e.g., producer/consumer, predator/prey, parasite/host, relationships that are mutually beneficial or competitive)

**Std 6, Gr 6-8, Bmrk 3*
†CA (4); OH (5); SC (5); SD (5)



Grades 5-6

Knows how energy is transferred through food webs in an ecosystem (e.g., energy enters ecosystems as sunlight, and green plants transfer this energy into chemical energy through photosynthesis; this chemical energy is passed from organism to organism; animals get energy from oxidizing their food, releasing some of this energy as heat)

**Std 6, Gr 6-8, Bmrk 4*
†CA (6); OH (6); SC (5); SD (6)

TOPIC 15: POPULATIONS AND ECOSYSTEMS

Grade 1-4

Knows that living things are found almost everywhere in the world and that distinct environments support the life of different types of plants and animals

**Std 6, Gr K-2, Bmrk 2
†CA (1); OH (1); SC (4); SD (2)*



Grades 4-7

Knows that all individuals of a species that exist together at a given place and time make up a population, and that all populations living together and the physical factors with which they interact compose an ecosystem

**Std 6, Gr 6-8, Bmrk 1
†CA (4); OH (7); SC (5); SD (4)*

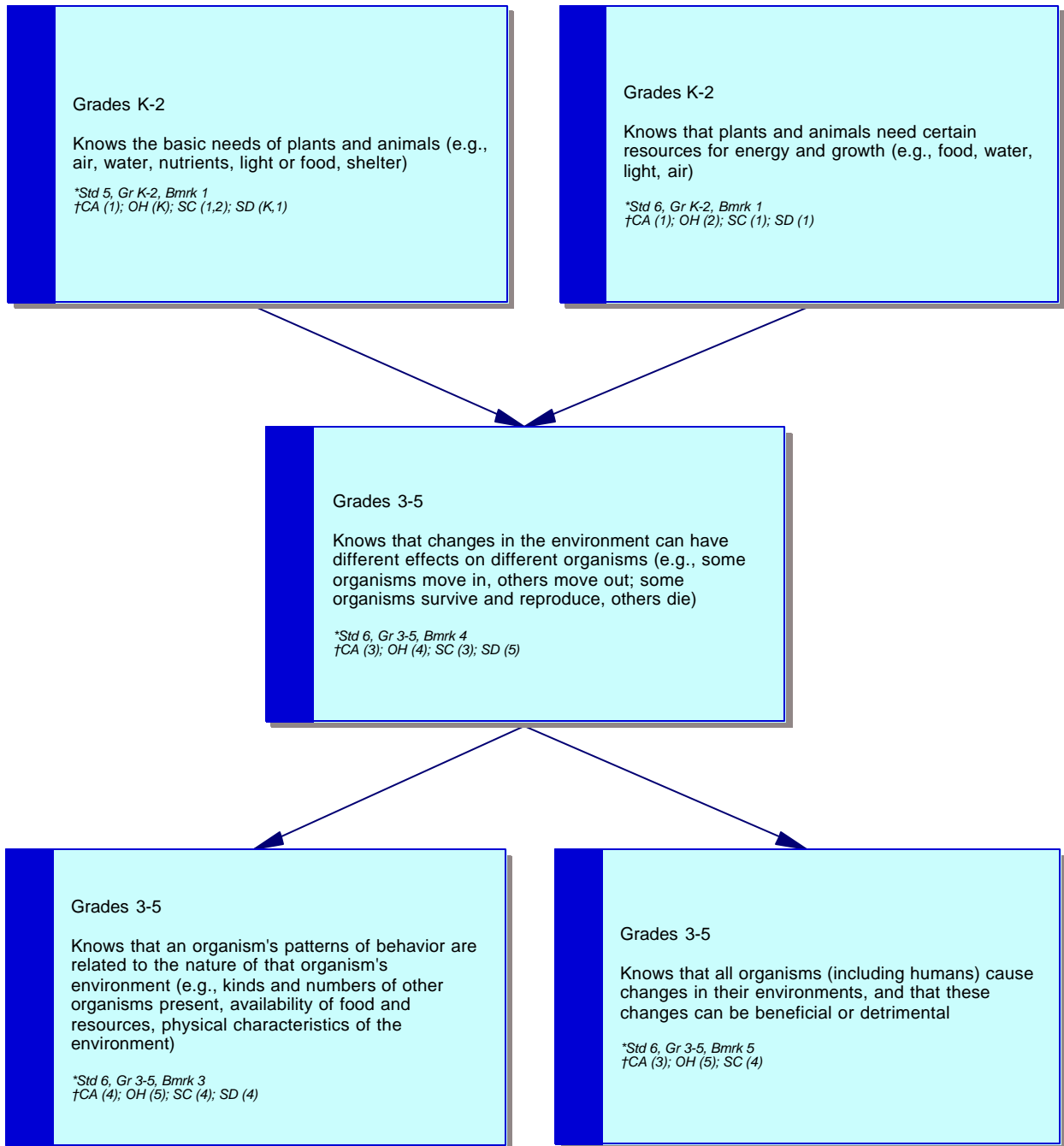


Grades 5-7

Knows factors that affect the number and types of organisms an ecosystem can support (e.g., available resources; abiotic factors such as quantity of light and water, range of temperatures, and soil composition; disease; competition from other organisms within the ecosystem; predation)

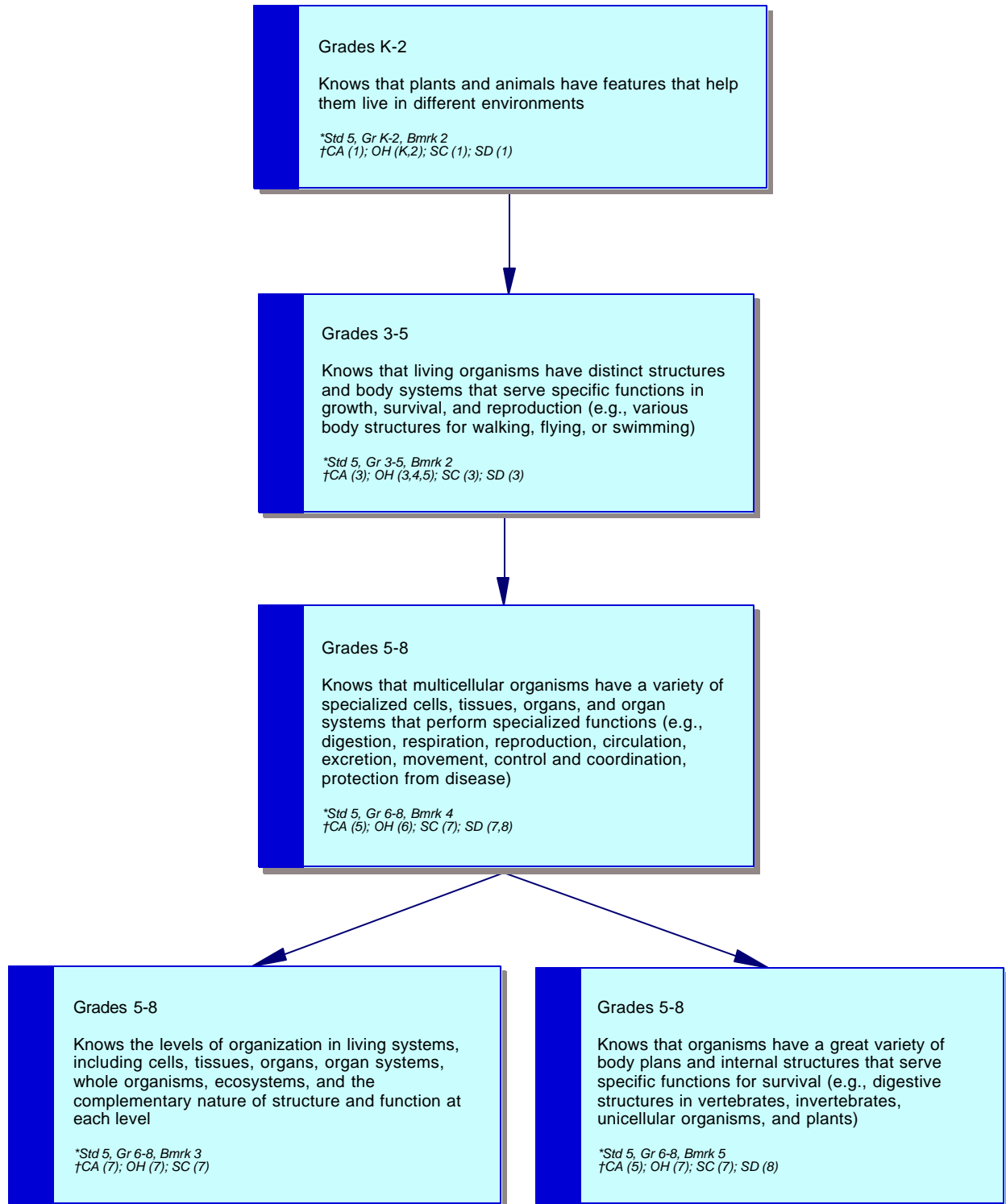
**Std 6, Gr 6-8, Bmrk 2
†CA (6); OH (7); SC (5); SD (7)*

TOPIC 16: RELATIONSHIPS BETWEEN ORGANISMS AND THE ENVIRONMENT



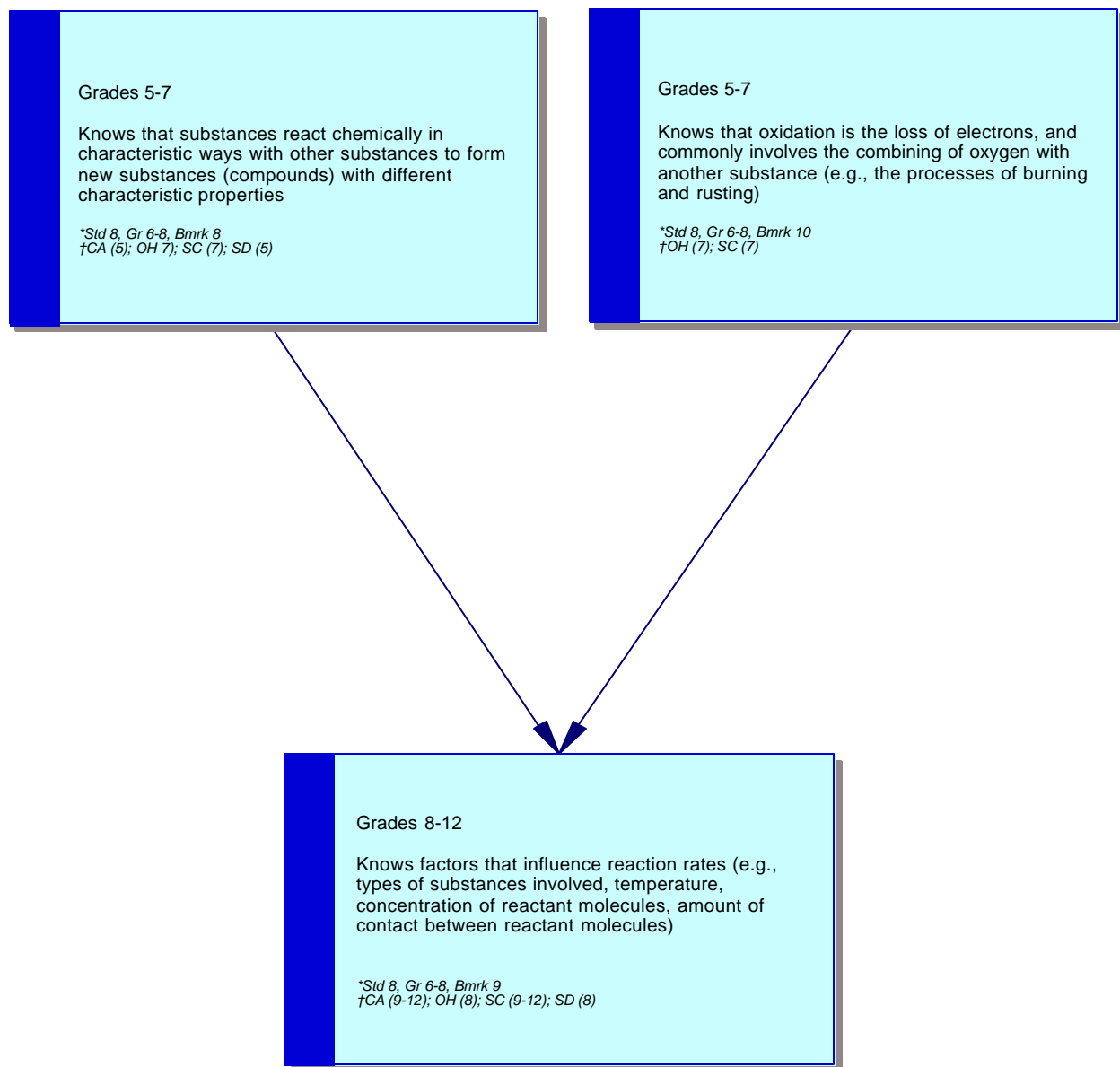
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 17: STRUCTURE AND FUNCTION IN ORGANISMS



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 18: CHEMICAL REACTIONS



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 19: CONSERVATION OF MATTER AND ENERGY

Grade 6-7

Knows how matter is recycled within ecosystems (e.g., matter is transferred from one organism to another repeatedly, and between organisms and their physical environment; the total amount of matter remains constant, even though its form and location change)

**Std 6, Gr 6-8, Bmrk 5*
†CA (6); OH (6); SC (7); SD (7)



Grades 7-8

Understands the conservation of mass in physical and chemical change (e.g., no matter how substances within a closed system interact with one another, the total weight of the system remains the same; the same number of atoms of a single element weighs the same, no matter how the atoms are arranged)

**Std 8, Gr 6-8, Bmrk 6*
†CA (8); OH (8); SC (7); SD (7,8)

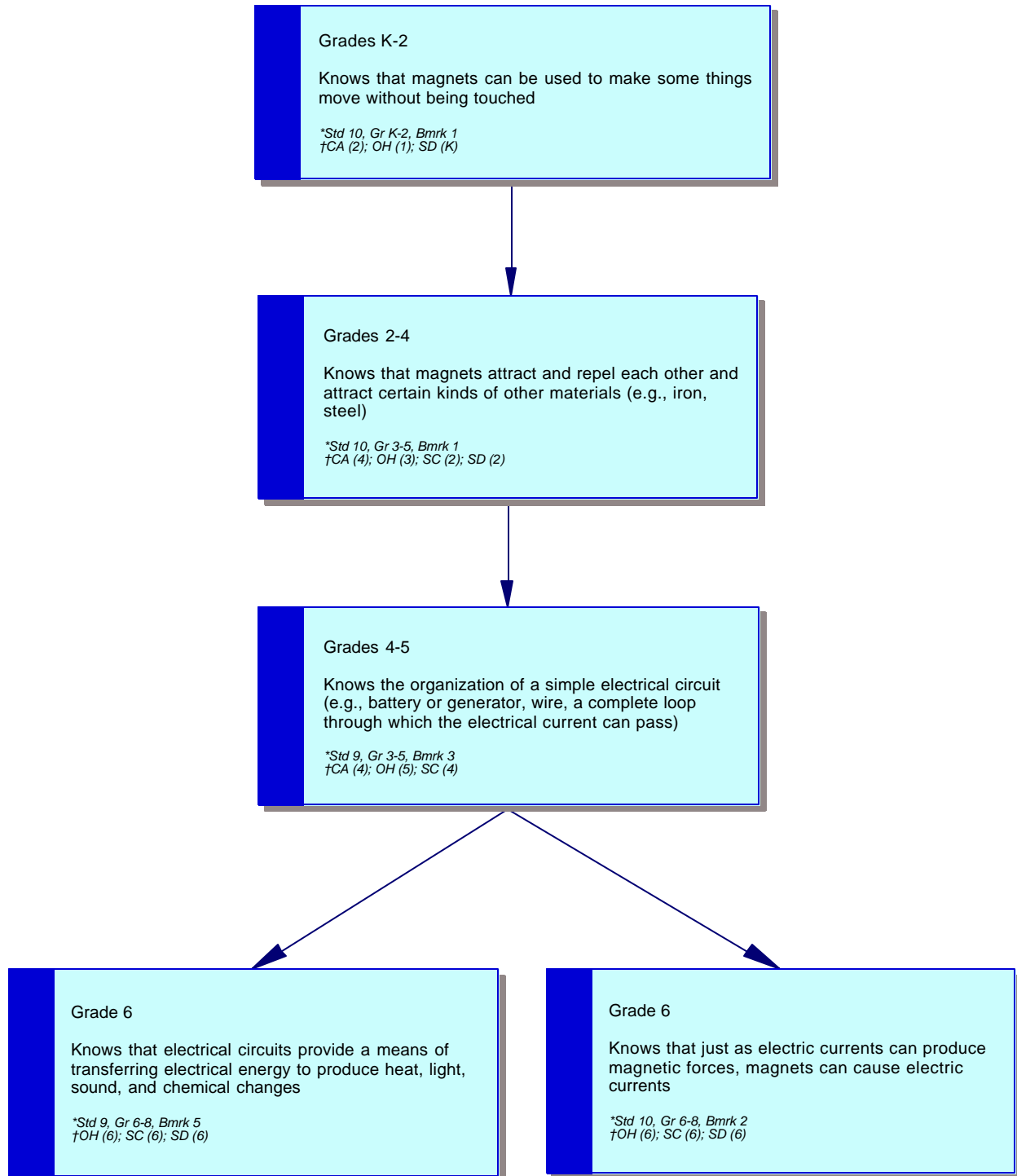


Grades 7-12

Understands the law of conservation of energy (i.e., energy cannot be created or destroyed but only changed from one form to another)

**Std 9, Gr 6-8, Bmrk 2*
†CA (9-12); OH (8); SC (9-12); SD (7)

TOPIC 20: ELECTRICITY AND MAGNETISM



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 21: ENERGY TRANSFER AND ENTROPY

Grade 3-6

Knows that heat can move from one object to another by conduction and that some materials conduct heat better than others

**Std 9, Gr 3-5, Bmrk 2*
†CA (6); OH (5); SC (3); SD (5)



Grades 4-6

Knows that electrical circuits provide a means of transferring electrical energy to produce heat, light, sound, and chemical changes

**Std 9, Gr 6-8, Bmrk 5*
†CA (4); OH (6); SC (6); SD (6)

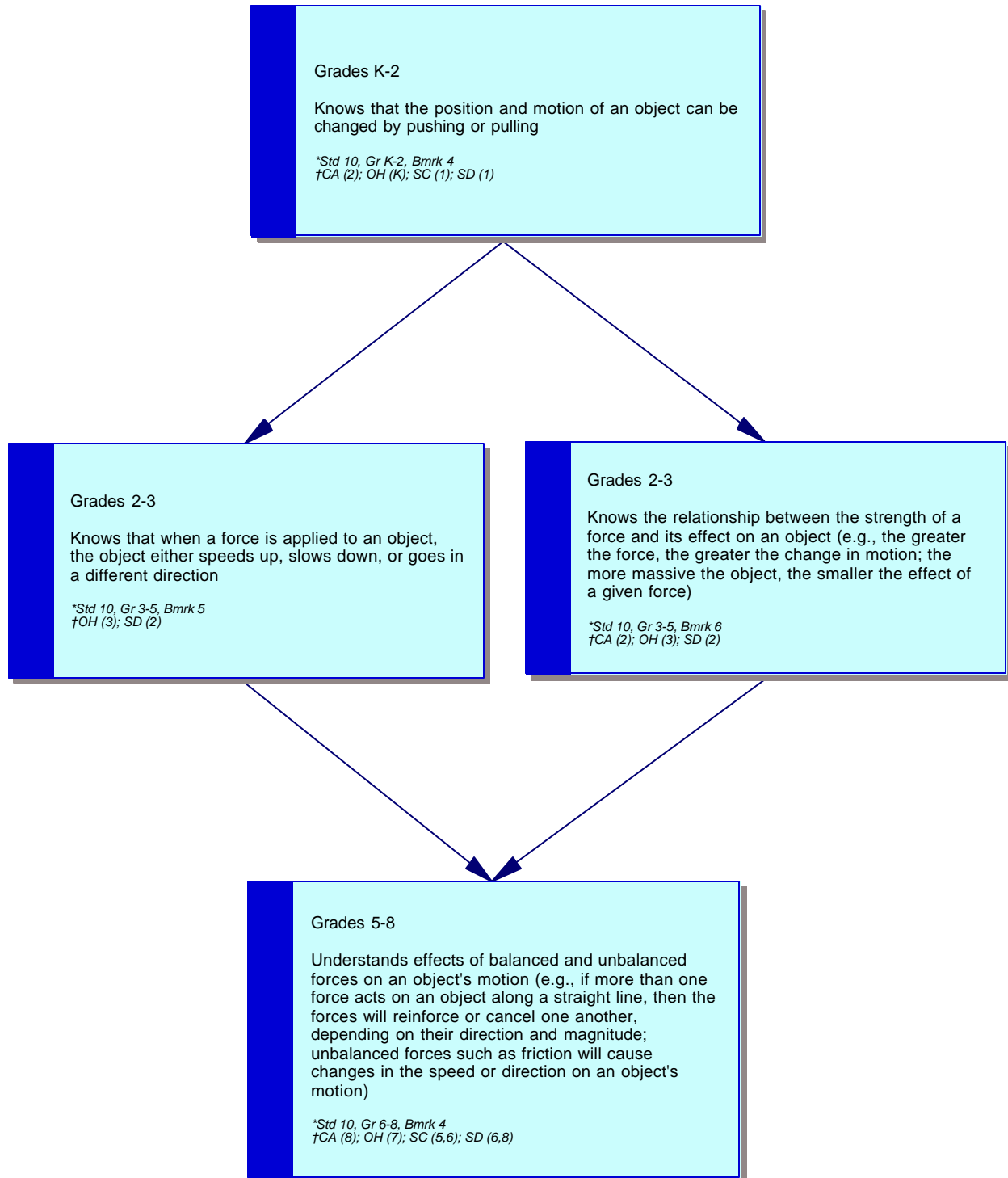


Grades 6-8

Knows that heat energy flows from warmer materials or regions to cooler ones through conduction, convection, and radiation

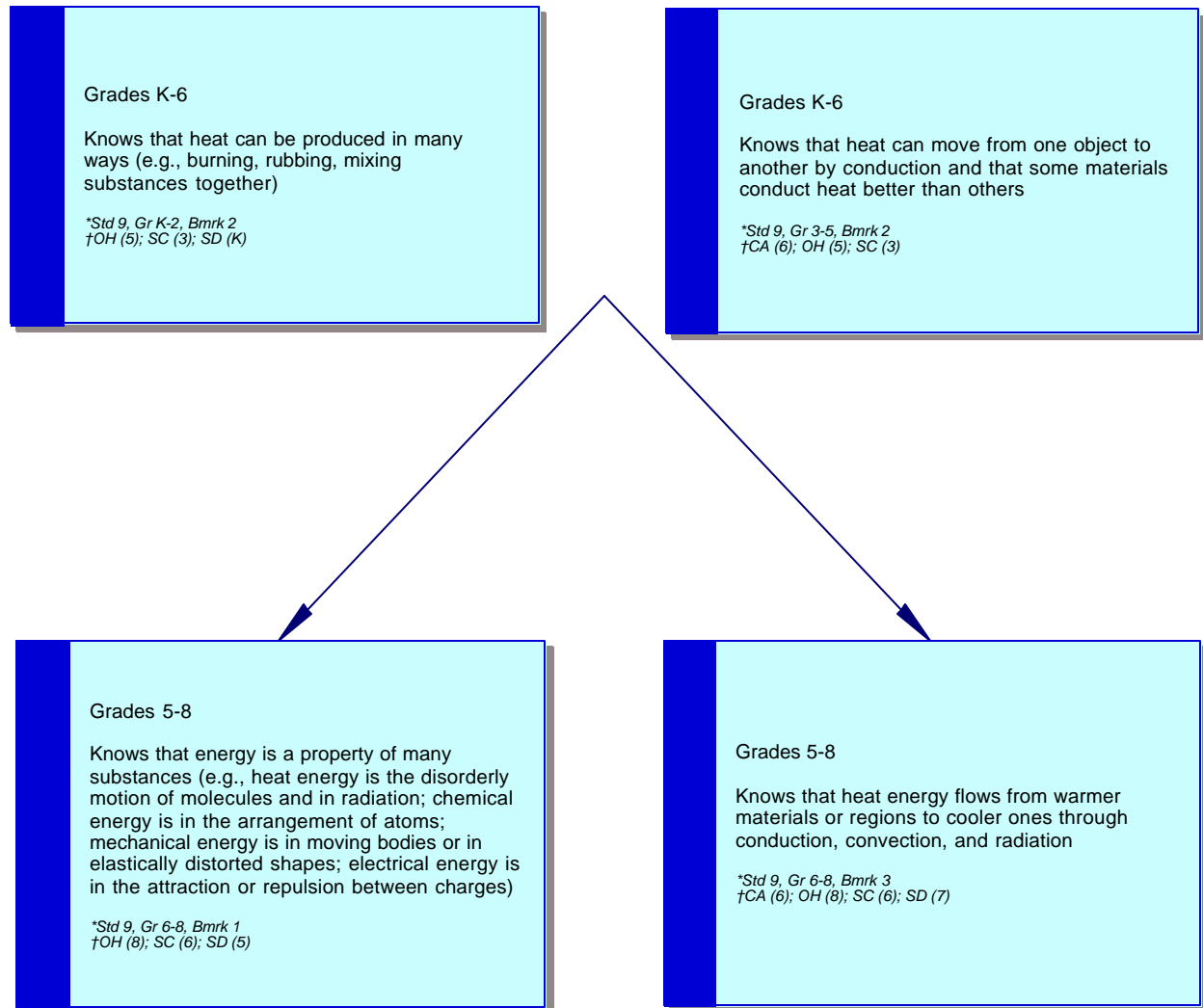
**Std 9, Gr 6-8, Bmrk 3*
†CA (6); OH (8); SC (6); SD (7)

TOPIC 22: FORCES AND MOTION

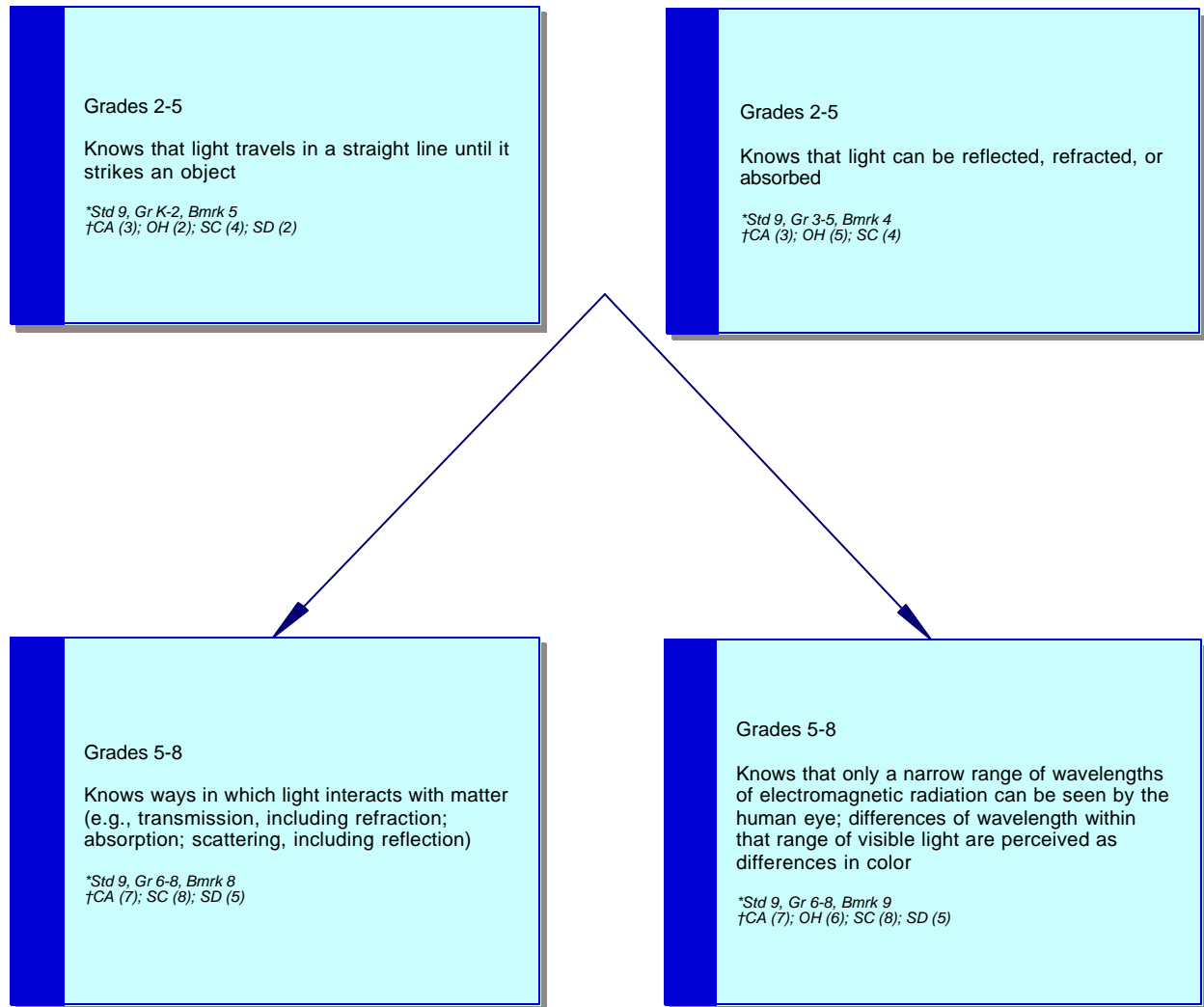


**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 23: FORMS OF ENERGY (HEAT ENERGY)

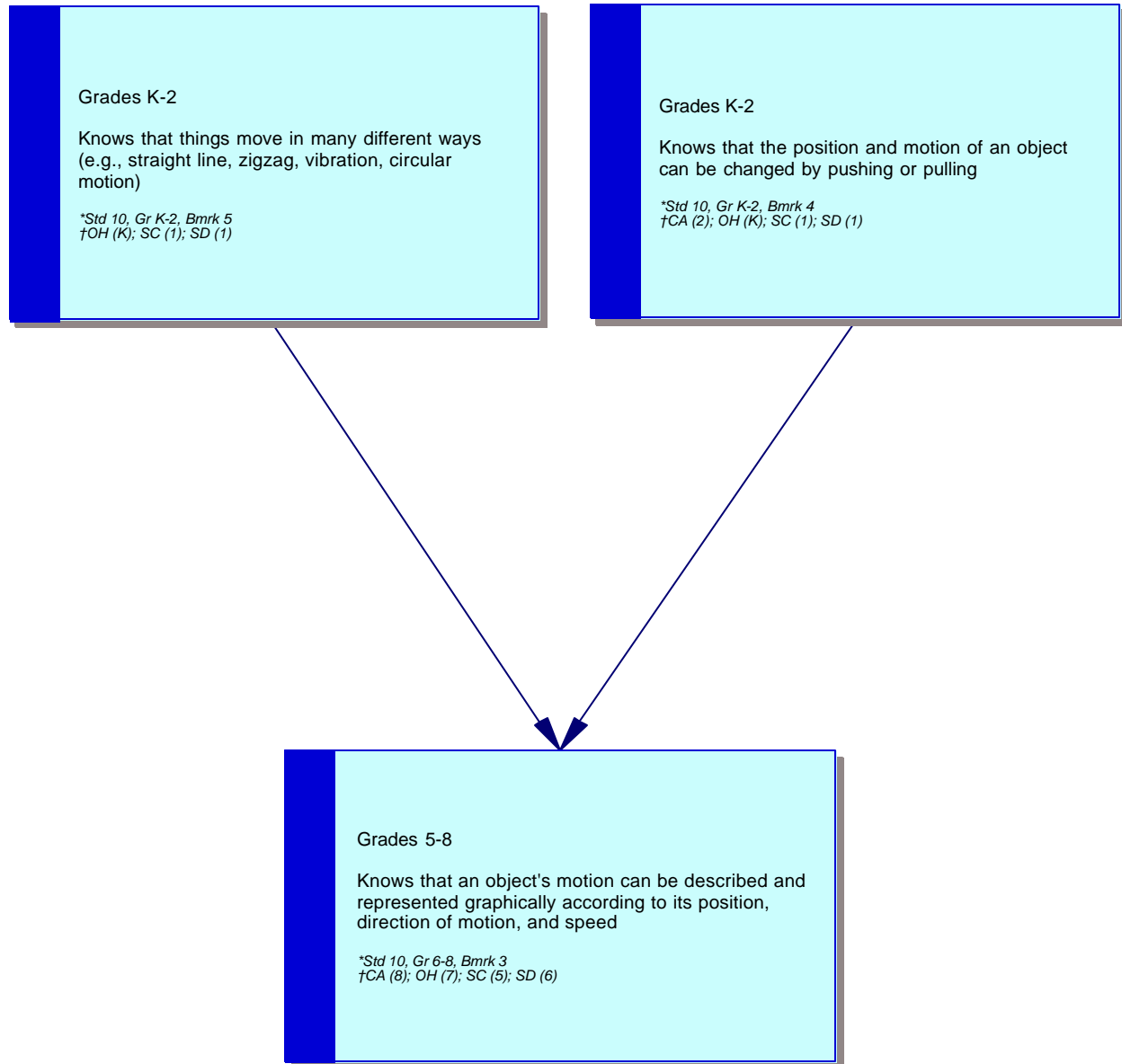


TOPIC 24: FORMS OF ENERGY (LIGHT ENERGY)



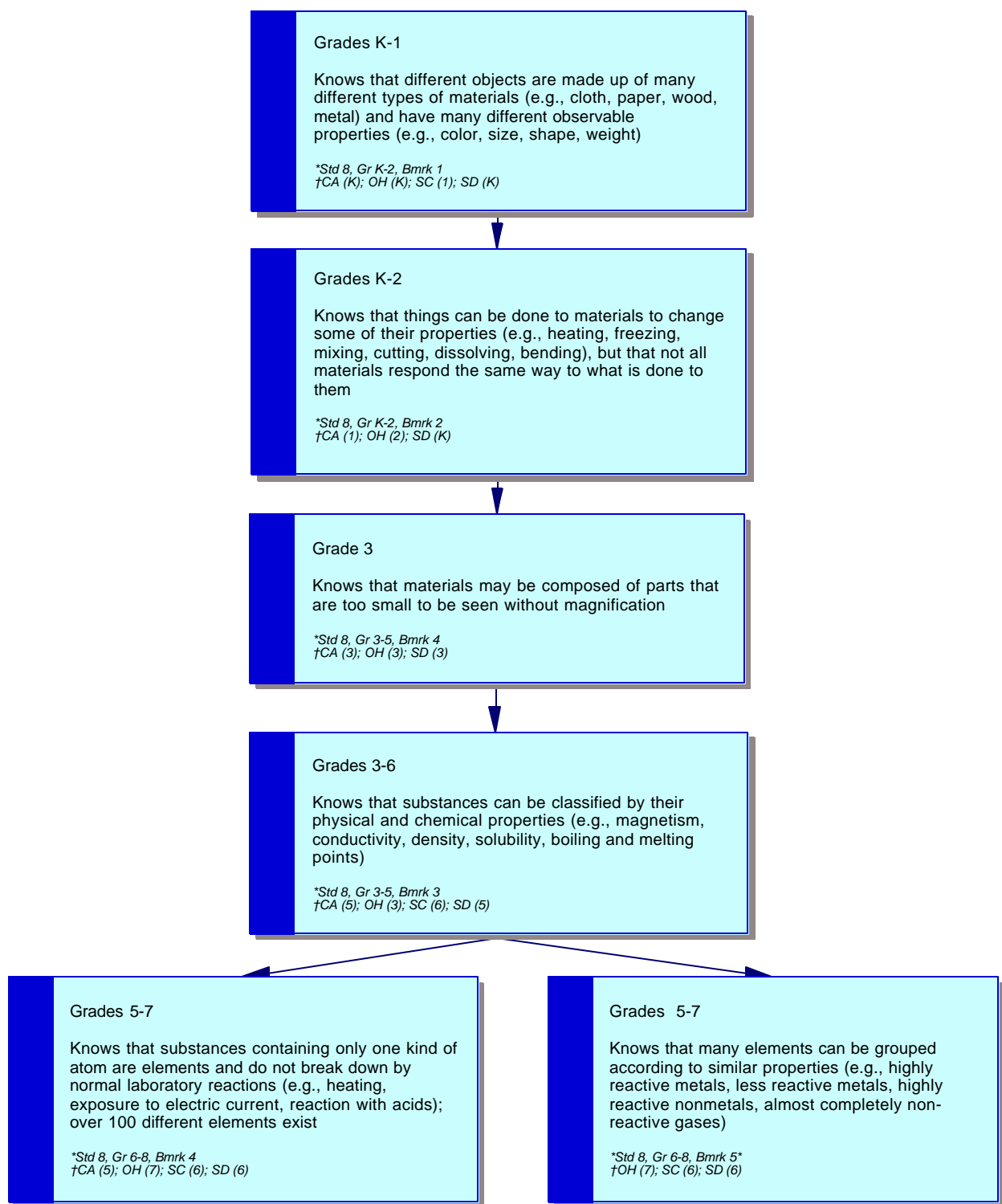
**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 25: POSITION AND MOTION



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

TOPIC 26: PROPERTIES OF SUBSTANCES



**Benchmark reference: Location within McREL's Compendium available online at <http://www.mcrel.org/standards-benchmarks/>
†Supporting Documents & Grade Level: State standards document that supports proposed grade sequencing*

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