Georgia Draft Science Descriptions

Georgia Biology Curriculum:
"The Georgia Chemistry [sic] Curriculum is designed to provide students the necessary tools to be proficient in biology. *The Council for Basic Education* and *Project 2061's Benchmarks for Science Literacy* were used as a guide to determine appropriate content and process skills for students."
–GaBioCur.pdf, downloaded from http://www.glc.k12.ga.us/spotlight/gps2.htm

For each draft description **changes** or **additions** to the Project 2061 Benchmarks are highlighted in **green**. [**Omissions**] from the 2061 text are highlighted in [**red**], within square brackets. Unmarked text is identical to 2061. References to the relevant Benchmarks follow each section.

Kindergarten through Second Grade Student/Curriculum Descriptions

Source: K-2Sci.pdf downloaded from http://www.glc.k12.ga.us/spotlight/gps2.htm
Compared to Project 2061 Benchmarks Online:
http://www.project2061.org/tools/benchol/ch4/ch4.htm
http://www.project2061.org/tools/benchol/ch5/ch5.htm

The Universe

During these years, learning about objects in the sky should be entirely observational and qualitative, for the children are far from ready to understand the magnitudes involved or to make sense out of explanations. The priority is to get the students noticing and describing what the sky looks like to them at different times. They should, for example, observe how the moon appears to change its shape. But it is too soon to name all the moon's phases and much too soon to explain them.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Universe_K_2

The Earth

There are many ways to acquaint children with earth-related phenomena that they will only come to understand later as being cyclic. For instance, students can start to keep daily records of temperature (hot, cold, pleasant) and precipitation (none, some, lots), and plot them by week, month, and years. It is enough for students to spot the pattern of ups and downs, without getting deeply into the nature of climate. They should become familiar with the freezing of water and melting of ice (with no change in weight), the disappearance of wetness into the air, and the appearance of water on cold surfaces. Evaporation and condensation will mean nothing different from disappearance and appearance, perhaps for several years, until students begin to understand that the evaporated water is still present in the form of invisibly small molecules. Teaching geological facts about how the face of the earth changes serves little purpose in these early years. Students should start becoming familiar with all aspects of their immediate surroundings, including what things change and what seems to cause change. Perhaps "changing things" can be a category in a class portfolio of things students observe and read about. At some point, students can start thinking up and trying out safe and helpful ways to change parts of their environment.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Earth_K_2

The Structure of Matter

Students should examine and use a wide variety of objects, categorizing them according to their various observable properties. They should subject materials to such treatments as mixing, heating, freezing, cutting, wetting, dissolving, bending, and exposing to light to see how they change. Even though it is too early to expect precise reports or even consistent results from the students, they should be encouraged to describe what they did and how materials responded.

Students should also get a lot of experience in constructing things from a few kinds of small parts ("Tinkertoys" and "Legos"), then taking them apart and rearranging them. They should begin to consider how the properties of objects may differ from properties of the materials they are made of. And they should begin to inspect things with a magnifying glass to discover features not visible without it.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#StructureOfMatter_K_2

No effort to introduce energy as a scientific idea ought to be organized in these first years. If children use the term energy to indicate how much pep they have, that is perfectly all right, in that the meaning is clear and no technical mischief has been done. By the end of the 2nd grade, students should be familiar with a variety of ways of making things go and should consider "What makes it go?" to be an interesting question to ask. Once they learn that batteries wear down and cars run out of gasoline, turning off unneeded appliances can be said to "save on batteries" and "save on gas." The idea that is accessible at this age is that keeping anything going uses up some resource. (Little is gained by having children answer, "Energy.")
http://www.project2061.org/tools/benchol/ch4/ch4.htm#EnergyTransformations_K_2

Motion and Forces

From the outset, students should view, describe, and discuss all kinds of moving things—themselves, insects, birds, trees, doors, rain, fans, swings, volleyballs, wagons, stars, etc.—keeping notes, drawing pictures to suggest their motion, and raising questions: Do they move in a straight line? Is their motion fast or slow? How can you tell? How many ways does a growing plant move? The questions count more than the answers, at this stage. And students should gain varied experiences in getting things to move or not to move and in changing the direction or speed of things that are already in motion.

Presumably students will start "making music" from the first day in school, and this provides an opportunity to introduce vibrations as a phenomenon rather than a theory. With the drums, bells, stringed and other instruments they use, including their own voices, they can feel the vibrations on the instruments as they hear the sounds. These experiences are important for their own sake and at this point do not need elaboration.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Motion_K_2

The focus should be on motion and on encouraging children to be observant about when and how things seem to move or not move. They should notice that things fall to the ground if not held up. They should observe motion everywhere, making lists of different kinds of motion and what things move that way. Even in the primary years, children should use magnets to get things to move without touching them, and thereby learn that forces can act at a distance with no perceivable substance in between.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#ForcesOfNature_K_2

Diversity of Life

All students, especially those who live in circumstances that limit their interaction with nature, must have the opportunity to observe a variety of plants and animals in the classroom, on the school grounds, in the neighborhood, at home, in parks and streams and gardens, and at the zoo; but observing is not enough. The students should have reasons for their observations—reasons that prompt them to do something with the information they collect. The reason can be to answer the students' own questions about how organisms live or care for their young. Some students may enjoy displaying, with drawings, photographs, or even real specimens, all the living things they can find where they live. The point is to encourage them to ask questions for which they can find answers by looking carefully (using hand lenses when needed) at plants and animals and then checking their observations and answers with one another.

The anthropomorphism embedded in most animal stories causes some worry. One suggestion is to ignore it. Stories sometimes give plants and animals attributes they do not have, but promoting student interest in reading is more important than giving students rigidly correct impressions in their reading. Students can be guided toward making distinctions between stories that portray animals the way they really are and those that do not. Differences among students over the correctness of the portrayal of animals or plants in books should lead the students to reference works, which are another source of information that students must start learning to use.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#DiversityOfLife_K_2

Heredity

Teachers should lead students to make observations about how the offspring of familiar animals compare to one another and to their parents. Children know that animals reproduce their own kind—rabbits have rabbits (but you can usually tell one baby rabbit from another), cats have kittens that have different markings (but cats never have puppies), and so forth. This idea should be strengthened by a large number of examples, both plant and animal, that the children can draw on.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Heredity_K_2

Cells

Emphasis should be placed on examining a variety of familiar animals and plants and considering things and processes they all need to stay alive, such as food and getting rid of wastes. Students should use hand lenses to make things appear 3 to 10 times bigger and more detailed and should be encouraged to wonder what they might see with more powerful lenses.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Cells_K_2

Interdependence of Life

Students should investigate the habitats of many different kinds of local plants and animals, including weeds, aquatic plants, insects, worms, and amphibians, and some of the ways in which animals depend on plants and on each other.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#InterdependenceOfLife_K_2

Flow of Matter and Energy

Children should begin to be aware of the basic parts of the food chain: Plants need sunlight to grow, some animals eat plants, and other animals eat both plants and animals. The key step that plants make

their own food is very difficult for elementary students and should be saved for middle school. An awareness of recycling, both in nature and in human societies, may play a helpful role in the development of children's thinking. Familiarity with the recycling of materials fosters the notion that matter continues to exist even though it changes from one form to another.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#FlowOfMatterAndEnergy_K_2

Biodiversity [Evolution of Life]
Students should begin to build a knowledge base about biological diversity. Student curiosity about fossils and dinosaurs can be harnessed to consider life forms that no longer exist. But the distinction between extinct creatures and those that still live elsewhere will not be clear for some time. "Long ago" has very limited meaning at this age level. Even as students make observations of organisms in their own environments, they can extend their experiences with other environments through **technology**.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#EvolutionOfLife_K_2

Third through Fifth Grade Student/Curriculum Descriptions

Source:3-5Sci.pdf downloaded from http://www.glc.k12.ga.us/spotlight/gps2.htm
Compared to Project 2061 Benchmarks Online:
http://www.project2061.org/tools/benchol/ch4/ch4.htm
http://www.project2061.org/tools/benchol/ch5/ch5.htm

The Universe
Students should begin to develop an inventory of the variety of things in the universe. Planets can be shown to be different from stars in two essential ways—their appearance and their motion. When a modest telescope or pair of binoculars is used instead of the naked eyes, stars only look brighter—and more of them can be seen. The brighter planets, however, clearly are disks. (Not very large disks except in good-sized telescopes, but impressive enough after seeing a lot of stars.) The fixed patterns of stars should be made more explicit, although learning the constellation names is not important in itself. When students know that the star patterns stay the same as they move across the sky (and gradually shift with the seasons), they can then observe that the planets change their position against the pattern of stars.

Once students have looked directly at the stars, moon, and planets, use can be made of photographs of planets and their moons and of various collections of stars to point out their variety of size, appearance, and motion. No particular educational value comes from memorizing their names or counting them, although some students will enjoy doing so. Nor should students invest much time in trying to get the scale of distances firmly in mind. As to numbers of stars in the universe, few children will have much of an idea of what a billion is; thousands are enough of a challenge. (At this stage, a billion means more than a person could ever count one-at-a-time in an entire lifetime.)

Students' grasp of many of the ideas of the composition and magnitude of the universe has to grow slowly over time. Moreover, in spite of its common depiction, the sun-centered system seriously conflicts with common intuition. Students may need compelling reasons to really abandon their earth-centered views. Unfortunately, some of the best reasons are subtle and make sense only at a fairly high level of sophistication.

[**Some ideas about light and sight are prerequisite to understanding astronomical phenomena. Children should learn early that a large light source at a great distance looks like a small light source that is much closer. This phenomenon should be observed directly (and, if possible, photographically) outside at night. How things are seen by their reflected light is a difficult concept for children at this age, but is probably necessary for them to learn before phases of the moon will make sense.**]
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Universe_3_5

The Earth
During this period, students can begin to learn some of the surface features of the earth and also the earth's relation to the sun, moon, and other planets. Films, computer simulations, a planetarium, and telescopic observations will help, but it is essential that all students, sometimes working together in small groups, make physical models and explain what the models show. At the same time, students can

begin learning about scale (counting, comparative distances, volumes, times, etc.) in interesting, readily understood activities and readings. However, scale factors larger than thousands, and even the idea of ratios, may be difficult before early adolescence.

An important point to be made along the way is that one cannot determine how the solar system is put together just by looking at it. Diagrams show what the system would look like if people could see it from far away, a feat that cannot be accomplished. Telescopes and other instruments do provide information, but a model is really needed to make sense out of the information. (The realization that people are not able to see, from the outside, how the solar system is constructed will help students understand the basis for the Copernican Revolution when the topic arises later.)

In making diagrams to show, say, the relative sizes of the planets and the distances of the planets from the sun, students may try to combine them using a single scale—and quickly become frustrated. Perhaps this can lead to a discussion of the general limits of graphic methods including photgraphs) for showing reality. In any case, at this stage a rough picture of the organization of the solar system is enough.

Water offers another important set of experiences for students at this level. Students can conduct investigations that go beyond the observations made in the earlier grades to learn the connection between liquid and solid forms, but recognizing that water can also be a gas, while much more difficult, is still probably accessible. Perhaps the main thrust there is to try to figure out where water in an open container goes. This is neither self-evident nor easy to detect. But the water cycle is of such profound importance to life on earth that students should certainly have experiences that will in time contribute to their understanding of evaporation, condensation, and the conservation of matter.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Earth_3_5

In these years, students should accumulate more information about the physical environment, becoming familiar with the details of geological features, observing and mapping locations of hills, valleys, rivers, etc., but without elaborate classification. Students should also become adept at using magnifiers to inspect a variety of rocks and soils. The point is not to classify rigorously but to notice the variety of components.

Students should now observe elementary processes of the rock cycle—erosion, transport, and deposit. Water and sand boxes and rock tumblers can provide them with some firsthand examples. Later, they can connect the features to the processes and follow explanations of how the features came to be and still are changing. Students can build devices for demonstrating how wind and water shape the land and how forces on materials can make wrinkles, folds, and faults. Films of volcanic magma and ash ejection dramatize another source of buildup.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#ProcessesThatShapeEarth_3_5

The Structure of Matter

The study of materials should continue and become more systematic and quantitative. Students should design and build objects that require different properties of materials. They should write clear descriptions of their designs and experiments, present their findings whenever possible in tables and graphs (designed by the students, not the teacher), and enter their data and results in a computer database.

Objects and materials can be described by more sophisticated properties—conduction of heat and electricity, buoyancy, response to magnets, solubility, and transparency. Students should measure, estimate, and calculate sizes, capacities, and weights. If young children can't feel the weight of something, they may believe it to have no weight at all. Many experiences of weighing (if possible on increasingly sensitive balances)—including weighing piles of small things and dividing to find the weight of each—will help. It is not obvious to elementary students that wholes weigh the same as the sum of their parts. That idea is preliminary to, but far short of, the conservation principle to be learned later that weight doesn't change in spite of striking changes in other properties as long as all the parts (including invisible gases) are accounted for.

With magnifiers, students should inspect substances composed of large collections of particles, such as salt and talcum powder, to discover the unexpected details at smaller scales. They should also observe and describe the behavior of large collections of pieces—powders, marbles, sugar cubes, or wooden blocks (which can, for example, be "poured" out of a container) and consider that the collections may have new properties that the pieces do not.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#StructureOfMatter_3_5

Energy Transformation

Investing much time and effort in developing formal energy concepts can wait. The importance of energy, after all, is that it is a useful idea. It helps make sense out of a very large number of things that go on in the physical and biological and engineering worlds. But until students have reached a certain point in their understanding of bits and pieces of the world, they gain little by having such a tool. It is a matter of timing.

The one aspect of the energy story in which students of this age can make some headway is heat, which is produced almost everywhere. In their science and technology activities during these years, students should be alerted to look for things and processes that give off heat—lights, radios, television sets, the sun, sawing wood, polishing surfaces, bending things, running motors, people, animals, etc.—and then for those that seem not to give off heat. Also, the time is appropriate to explore how heat spreads from one place to another and what can be done to contain it or shield things from it.

Students' ideas of heat have many wrinkles. In some situations, cold is thought to be transferred rather than heat. Some materials may be thought to be intrinsically warm (blankets) or cold (metals). Objects that keep things warm—such as a sweater or mittens—may be thought to be sources of heat. Only a continuing mix of experiment and discussion is likely to dispel these ideas.

Students need not come out of this grade span understanding heat or its difference from temperature. In this spirit, there is little to be gained by having youngsters refer to heat as heat energy. More important, students should become familiar with the warming of objects that start out cooler than their environment, and vice versa. Computer labware probes and graphic displays that detect small changes in temperature and plot them can be used by students to examine many instances of heat exchange. Because many students think of cold as a substance that spreads like heat, there may be some advantage in translating descriptions of transfer of cold into terms of transfer of heat.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#EnergyTransformations_3_5

Motion and Forces
Students should continue describing motion. And they can be more experimental and more quantitative as their measurement skills sharpen. Determining the speed of fast things and slow things can present a challenge that students will readily respond to. They also can work out for themselves some of the general relationships between force and change of motion and internalize the notion of force as a push or pull of one thing on another—whether rubber bands, magnets, or explosions.

Students should also increase their inventory of examples of periodic motion and perhaps devise ways of measuring different rates of vibration. And students should use prisms to see that white light produces a whole "rainbow" of colors. (The idea that white light is "made up of" different colors is difficult and should be postponed to later grades.) There is nothing to be gained at this stage, however, from linking light to wave motion. The main notion to convey here is that forces can act at a distance. Students should carry out investigations to become familiar with the pushes and pulls of magnets and static electricity. The term gravity may interfere with students' understanding because it often is used as an empty label for the common (and ancient) notion of "natural motion" toward the earth. The important point is that the earth pulls on objects.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Motion_3_5

Diversity of Life
Students should have the opportunity to learn about an increasing variety of living organisms, both the familiar and the exotic, and should become more precise in identifying similarities and differences among them. Although the emphasis can still be on external features, finer detail than before should be included. Hand lenses, introduced earlier, should now be routinely used by students. Microscopes should come into use, not to study cell structure but to begin exploring the world of organisms that cannot be seen by the unaided eye. Fortunately, wealth of films exists to supplement direct observation.

As students become more familiar with the characteristics of more and more organisms, they should be asked to invent schemes for classifying them--but without using the Linnean classification system. Hopefully, their classification schemes will vary according to the uses made of them as well as according to gross anatomy, behavior patterns, habitats, and other features. The aim is to move students toward the realization that there are many ways to classify things but how good any classification is depends on its usefulness. A scheme is useful if it contributes either to making decisions on some matter or to a deeper understanding of the relatedness of organisms. Classification schemes will, of course, vary with purpose (pets/nonpets; edible/nonedible).
http://www.project2061.org/tools/benchol/ch5/ch5.htm#DiversityOfLife_3_5

[**Evolution of Life**]
Students can begin to look for ways in which organisms in one habitat differ from those in another and consider how some of those differences are helpful to survival. The focus should be on the consequences of different features of organisms for their survival and reproduction. The study of fossils that preserve plant and animal structures is one approach to looking at characteristics of organisms. Evidence for the similarity within diversity of existing organisms can draw upon students' expanding knowledge of anatomical similarities and differences.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#EvolutionOfLife_3_5

Heredity

Students should move from describing individuals directly (she has blue eyes) to naming traits and classifying individuals with respect to those traits (eye color: blue). Students can be encouraged to keep lists of things that animals and plants get from their parents, things that they don't get, and things that the students are not sure about either way. This is also the time to start building the notion of a population whose members are alike in many ways but show some variation.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Heredity_3_5

Cells

Students' experiences should expand to include the observation of microscopic organisms, so the scale of magnification should increase to 30- or 100-power (dissection scope or low power on microscopes). Watching microorganisms is always informative, but some events are so rare that prepared materials are a necessity. Students can observe films of living cells growing and dividing, taking in substances, and changing direction when they run into things. Some students may reason that because these tiny cells are alive, they probably have the same needs as other, larger organisms. That can stimulate discussions about how single-celled organisms satisfy their need for food, water, and air.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Cells_3_5

Interdependence of Life

Students should explore how various organisms satisfy their needs in the environments in which they are typically found. They can examine the survival needs of different organisms and consider how the conditions in particular habitats can limit what kinds of living things can survive. Their studies of interactions among organisms within an environment should start with relationships they can directly observe. By viewing nature films, students should see a great diversity of life in different habitats.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#InterdependenceOfLife_3_5

Flow of Matter and Energy

Students should begin to notice that substances may change form and move from place to place, but they never appear out of nowhere and never just disappear. Questions should encourage students to consider where substances come from and where they go and to be puzzled when they cannot account for the origin or the fate of a substance. It's all right to start students on chains of what eats what in various environments, but labeling the steps in the chain as energy transfer is not necessary. Transfers of energy at this level are better illustrated in physical systems; biological energy transfer is far too complicated. http://www.project2061.org/tools/benchol/ch5/ch5.htm#FlowOfMatterAndEnergy_3_5

Middle School Science Descriptions

Source: 6-8Sci.pdf downloaded from http://www.glc.k12.ga.us/spotlight/gps2.htm
Compared to Project 2061 Benchmarks Online:
http://www.project2061.org/tools/benchol/ch4/ch4.htm
http://www.project2061.org/tools/benchol/ch5/ch5.htm

Earth Science

Students should add more detail to their picture of the universe, pay increasing attention to matters of scale, and back up their understanding with activities using a variety of astronomical tools. Student access to star finders, telescopes, computer simulations of planetary orbits, or a planetarium can be useful at this level. Figuring out and constructing models of size and distance—for example, of the planets within the solar system—is probably the most effective activity. Models with three dimensions are preferable to pictures and diagrams. Everyone should experience trying to fashion a physical model of the solar system in which the same scale is used for the sizes of the objects and the distances between them (as distinct from most illustrations, in which distances are underrepresented by a factor of 10 or more).
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Universe_6_8

Students can now consolidate their prior knowledge of the earth (as a planet) by adding more details (especially about climate), getting a firmer grasp of the geometry involved in explaining the seasons and phases of the moon, improving their ability to handle scale, and shifting their frame of reference away from the earth when needed. An inevitable paradox of the large scales involved is that an ocean that is difficult to imagine being 7 miles deep also can be considered a "relatively thin" layer on the earth's surface. Students should exercise their understanding of the paradox, perhaps by debating provocative questions such as "Is the ocean amazingly deep or amazingly shallow?"

Gravity, earlier thought of as acting toward the ground, can by now be thought of as acting toward the center of the spherical earth and reaching indefinitely into space. It is also time for students to begin to look at the planet's role in sustaining life—a complex subject that involves many different issues and benchmarks. In this section, the emphasis is on water and air as essential resources.

The cause of the seasons is a subtle combination of global and orbital geometry and of the effects of radiation at different angles. Students can learn part of the story at this grade level, but a complete picture cannot be expected until later.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Earth_6_8

At this level, students are able to complete most of their understanding of the main features of the physical and biological factors that shape the face of the earth. This understanding will still be descriptive because the theory of plate tectonics will not be encountered formally until high school. Of course, students should see as great a variety of landforms and soils as possible.

It is especially important that students come to understand how sedimentary rock is formed periodically, embedding plant and animal remains and leaving a record of the sequence in which the plants and animals appeared and disappeared. Besides the relative age of the rock layers, the

absolute age of those remains is central to the argument that there has been enough time for evolution of species. The process of sedimentation is understandable and observable. But imagining the span of geologic time will be difficult for students.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#ProcessesThatShapeEarth_6_8

Some experiences with how apparent positions of objects differ from different points of observation will make plausible the estimation of distances to the moon and sun. Finding distances by triangulation and scale drawings will help students to understand how the distances to the moon and sun were estimated and why the stars must be very much farther away. (The dependence of apparent size on distance can be used to pose the historically important puzzle that star patterns do not appear any larger from one season to the next, even though the earth swings a hundred million miles closer to them.)

Using light years to express astronomical distances is not as straightforward as it seems. (Many adults think of light years as a measure of time.) Beginning with analogs such as "automobile hours" may help
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Universe_6_8

Life Science

Science in the middle grades should provide students with opportunities to enrich their growing knowledge of the diversity of life on the planet and to begin to connect that knowledge to what they are learning in geography. That is, whenever students study a particular region in the world, they should learn about the plants and animals found there and how they are like or unlike those found elsewhere. Tracing simple food webs in varied environments can contribute to a better understanding of the dependence of organisms (including humans) on their environment.

Students should begin to extend their attention from external anatomy to internal structures and functions. Patterns of development may be brought in to further illustrate similarities and differences among organisms. Also, they should move from their invented classification systems to those used in modern biology. That is not done to teach them the standard system but to show them what features biologists typically use in classifying organisms and why. Classification systems are not part of nature. Rather, they are frameworks created by biologists for describing the vast diversity of organisms, suggesting relationships among living things, and framing research questions. A provocative exercise is to have students try to differentiate between familiar organisms that are alike in many ways—for example, between cats and small dogs.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#DiversityOfLife_6_8

Now is the time to begin the study of genetic traits—what offspring get from parents. [**This topic can be handled as a natural part of the study of human reproduction.**] Students should examine examples of lineages for which breeding has been used to emphasize or suppress certain features of organisms.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Heredity_6_8

Once they have some "magnification sense," students can use photomicrographs to extend their observations of cells, gradually concentrating on cells that make up internal body structures. [**The**

main interest of youngsters at this level is the human body, so they can begin with as many different kinds of body cells as possible—nerve, bone, muscle, skin—and then move on to] Examining cells in other animals and plants [**This activity**] can show students that cells are the fundamental building blocks of their own bodies and of other living things as well. Also, once students see that tissue in other animals looks pretty much the same as tissue in humans, two important claims of science will be reinforced: the ubiquity of cells and the unity of nature.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Cells_6_8

As students build up a collection of cases based on their own studies of organisms, readings, and film presentations, they should be guided from specific examples of the interdependency of organisms to a more systematic view of the kinds of interactions that take place among organisms. But a necessary part of understanding complex relationships is to know what a fair proportion of the possibilities are. The full-blown concept of ecosystem (and that term) can best be left until students have many of the pieces ready to put in place. Prior knowledge of the relationships between organisms and the environment should be integrated with students' growing knowledge of the earth sciences.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#InterdependenceOfLife_6_8

In the middle grades, the emphasis is on following matter through ecosystems. Students should trace food webs both on land and in the sea. The food webs that students investigate should first be local ones they can study directly. The use of films of food webs in other ecosystems can supplement their direct investigations but should not substitute for them. Most students see food webs and cycles as involving the creation and destruction of matter, rather than the breakdown and reassembly of invisible units. They see various organisms and materials as consisting of different types of matter that are not convertible into one another. Before they have an understanding of atoms, the notion of reusable building blocks common to plants and animals is quite mysterious. So following matter through ecosystems needs to be linked to their study of atoms.

Students' attention should be drawn to the transfer of energy that occurs as one organism eats another. It is important that students learn the differences between how plants and animals obtain food and from it the energy they need. The first stumbling block is food, which represents one of those instances in which differences between the common use of a term and the technical one cause persistent confusion. In popular language, food is whatever nutrients plants and animals must take in if they are to grow and survive (solutions of minerals that plants need traces of frequently bear the label "plant food"); in scientific usage, food refers only to those substances, such as carbohydrates, proteins, and fats, from which organisms derive the energy they need to grow and operate and the material of which they are made. It's important to emphasize that the sugars that plants make out of water and carbon dioxide are their only source of food. Water and minerals dissolved in it are not sources of energy for plants or for animals.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#FlowOfMatterAndEnergy_6_8

During middle school, several lines of evidence are further developed. The fossil evidence can be expanded beyond extinctions and survivals to the notion of **biological** [**evolutionary**] history. Sedimentation of rock can be brought in to show relative age. However, actual age, which requires an understanding of isotopic dating techniques, should wait until high school, when students learn about the structure of atoms. Breeding experiments can illustrate the heritability of traits and the effects of

selection. [**It was familiarity with selective breeding that stimulated Darwin's thinking that differences between successive generations can naturally accumulate.**]
http://www.project2061.org/tools/benchol/ch5/ch5.htm#EvolutionOfLife_6_8

Physical Science

[**The structure of matter is difficult for this grade span.**] Historically, much of the evidence and reasoning used in developing atomic/molecular theory was complicated and abstract. In traditional curricula too, very difficult ideas have been offered to children before most of them had any chance of understanding. The law of definite proportions in chemical combinations, so obvious when atoms (and proportions) are well understood, is not likely to be helpful at this level. The behavior of gases—such as their compressibility and their expansion with temperature—may be investigated for qualitative explanation; but the mathematics of quantitative gas laws is likely to be more confusing than helpful to most students. When students first begin to understand atoms, they cannot confidently make the distinction between atoms and molecules or make distinctions that depend upon it—among elements, mixtures, and compounds, or between "chemical" and "physical" changes. An understanding of how things happen on the atomic level—making and breaking bonds—is more important than memorizing the official definitions (which are not so clear in modern chemistry anyway). Definitions can, of course, be memorized with no understanding at all.

Going into details of the structure of the atom is unnecessary at this level, and holding back makes sense. By the end of the 8th grade, students should have sufficient grasp of the general idea that a wide variety of phenomena can be explained by alternative arrangements of vast numbers of invisibly tiny, moving parts. Possible differences in atoms of the same element should be avoided at this stage. Historically, the identical nature of atoms of the same element was an assumption of atomic theory for a very long time.

When isotopes are introduced later, to explain subsequent observations, they can be a surprise and a lesson in the nature of progress in science. The alternative—teaching atoms' variety at the same time as the notion of their identity—seems likely to be prohibitively confusing to most students.

To that end, students should become familiar with characteristics of different states of matter—now including gases—and transitions between them. Most important, students should see a great many examples of reactions between substances that produce new substances very different from the reactants. Then they can begin to absorb the rudiments of atomic/molecular theory, being helped to see that the value of the notion of atoms lies in the explanations it provides for a wide variety of behavior of matter. Each new aspect of the theory should be developed as an explanation for some observed phenomenon and grasped fairly well before going on to the next.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#StructureOfMatter_6_8

At this level, students should be introduced to energy primarily through energy transformations. Students should trace where energy comes from (and goes next) in examples that involve several different forms of energy along the way: heat, light, motion of objects, chemical, and elastically distorted materials. To change something's speed, to bend or stretch things, to heat or cool them, to push things together or tear them apart all require transfers (and some transformations) of energy.

At this early stage, there may be some confusion in students' minds between energy and energy sources. Focusing on energy transformations may get around this somewhat. Food, gasoline, and batteries obviously get used up. But the energy they contain does not disappear; it is changed into other forms of energy.

The most primitive idea is that the energy needed for an event must come from somewhere. That should trigger children's interest in asking, for any situation, where the energy comes from and (later) asking where it goes. Where it comes from is usually much more evident than where it goes, because some usually diffuses away as radiation and random molecular motion.

A slightly more sophisticated proposition is the semi-quantitative one that whenever some energy seems to show up in one place, some will be found to disappear from another. Eventually, the energy idea can become quantitative: If we can keep track of how much energy of each kind increases and decreases, we find that whenever the energy in one place decreases, the energy in other places increases by just the same amount. This energy-cannot-be-created-or-destroyed way of stating conservation fully may be more intuitive than the abstraction of a constant energy total within an isolated system. The quantitative (equal amounts) idea should probably wait until high school.

Convection is not so much an independent means of heat transfer as it is an aid to transfer of heat by conduction and radiation. Convection currents appear spontaneously when density differences caused by heating (conduction and radiation) are acted on by a gravitational field. (Though not in space stations, unless they are rotating.) But these subtleties are not appropriate for most 8th graders.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#EnergyTransformations_6_8

The force/motion relationship can be developed more fully now and the difficult idea of inertia be given attention. Students have no trouble believing that an object at rest stays that way unless acted on by a force; they see it every day. The difficult notion is that an object in motion will continue to move unabated unless acted on by a force. Telling students to disregard their eyes will not do the trick—the things around them do appear to slow down of their own accord unless constantly pushed or pulled. The more experiences the students can have in seeing the effect of reducing friction, the easier it may be to get them to imagine the friction-equals-zero case.

Students can now learn some of the properties of waves by using water tables, ropes, and springs, and quite separately they can learn about the electromagnetic spectrum, including the assertion that it consists of wavelike radiations. Wave length should be the property receiving the most attention but only minimal calculation.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Motion_6_8

The idea of gravity—up until now seen as something happening near the earth's surface—can be generalized to all matter everywhere in the universe. Some demonstration, in the laboratory or on film or videotape, of the gravitational force between objects may be essential to break through the intuitive notion that things just naturally fall. Students should make devices to observe the magnetic effects of current and the electric effects of moving magnets. At first, the devices can be simple electromagnets; later, more complex devices, such as motor kits, can be introduced.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#ForcesOfNature_6_8

High School Science Descriptions

Source: HSCourseDes.pdf downloaded from http://www.glc.k12.ga.us/spotlight/gps2.htm
Compared to Project 2061 Benchmarks Online:
http://www.project2061.org/tools/benchol/ch4/ch4.htm
http://www.project2061.org/tools/benchol/ch5/ch5.htm

Physical Sciences

Understanding the general architecture of the atom and the roles played by the main constituents of the atom in determining the properties of materials now becomes relevant. Having learned earlier, that all the atoms of an element are identical and are different from those of all other elements, students now come up against the idea that, on the contrary, atoms of the same element can differ in important ways. This revelation is an opportunity as well as a complication—scientific knowledge grows by modifications, sometimes radical, of previous theories. Sometimes advances have been made by neglecting small inconsistencies, and then further advances have been made later by attending closely to those inconsistencies.

Students may at first take isotopes to be something in addition to atoms or as only the unusual, unstable nuclides. The most important features of isotopes (with respect to general scientific literacy) are their nearly identical chemical behavior and their different nuclear stabilities. Insisting on the rigorous use of isotope and nuclide is probably not worthwhile, and the latter term can be ignored.

The idea of half-life requires that students understand ratios and the multiplication of fractions, and be somewhat comfortable with probability. Games with manipulative or computer simulations should help them in getting the idea of how a constant proportional rate of decay is consistent with declining measures that only gradually approach zero. The mathematics of inferring backwards from measurements to age is not appropriate for most students. They need only know that such calculations are possible.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#StructureOfMatter_9_12

The hands-on nature of the science curriculum standards increases the need for teachers to use appropriate precautions in the laboratory and field. It is recommended that micro-the physical sciences techniques be used where appropriate. The guidelines for the safe use, storage, and disposal of chemicals must be observed.

The concepts acquired in the earlier grades should now be extended to nuclear realms and living organisms. Revisiting energy concepts in new contexts provides opportunities to improve student understanding of the basic concepts and to see just how powerful they are.

Two other major ideas merit introduction during these years, but without resort to mathematics **(in physical science)**. One of these is that the total amount of energy available for useful transformation is almost always decreasing; the other is that energy changes on the atomic scale occur only in discrete jumps. The first of those is not too difficult or implausible for students because they can experience in many ways a wide variety of actions that give off heat. The emphasis should probably be on the practical consequences of the loss of useful energy through heat dissipation.

On the other hand, the notion that energy changes in atoms can occur in only fixed amounts with no intermediate values is strange to begin with and hard to demonstrate. Some evidence should be presented for this scientific belief but not in great detail. The easiest phenomenon to show, which is also a major reason for including quantum jumps in literacy, is the discrete colors of light emitted by separate atoms, as in sodium-vapor or mercury-vapor lights. Another major reason for having students encounter the quantum idea is to illustrate the point that in science it is sometimes useful to invent ideas that run counter to intuition and prior experience.

An important application of the atom/energy relationship to bring to the attention of students is that the distinctive light energies emitted or absorbed by different atoms enable them to be identified on earth, in our sun, and even on the other side of the universe. This fact is a prime example of the "rules are the same everywhere" principle.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#EnergyTransformations_9_12

At this level, students learn about relative motion, the action/reaction principle, wave behavior, the interaction of waves with matter, the Doppler effect now used in weather observations, and the red shift of distant galaxies. Relative motion is fun—students find it interesting to figure out their speeds in different reference frames, and many activities and films illustrate this principle. Learning this concept is important for its own sake and for the part it plays in the changing reference frames of the Copernican Revolution, and in simple relativity.

Students can move from a qualitative understanding of the force/motion relationship (more force changes motion more; more mass is harder to change) to one that is more quantitative (the change in motion is directly proportional to the amount of force and inversely proportional to the mass). Experimentally, they can learn that the change in motion of an object is proportional to the applied force and inversely proportional to the mass—a step beyond knowing that change in motion goes up with increasing force and down with increasing mass.

[**This level is also a time to show the power of mathematics. Once students are fully convinced that change in motion is proportional to the force applied, then mathematical logic requires that when F = 0, there be no change in motion. (So Newton's first law is just a special case of his second.)**] Students should come to understand qualitatively that (1) doubling the force on an object of a given mass doubles the effect the force has, tripling triples the effect, and so on; and (2) that whatever effect a given force has on an object, it will have half the effect on an object having twice the mass, a third on one having triple the mass, and so on. This need not entail having students solving lots of numerical problems.

The qualitative principle also applies to waves. Even as simple a relationship as speed = wavelength x frequency poses difficulties for many students. A sufficient minimum is that students develop semi-quantitative notions about waves—for example, higher frequencies have shorter wavelengths and those with longer wavelengths tend to spread out more around obstacles.

The effect of wavelength on how waves interact with matter can be developed through intrinsically interesting phenomena—such as the blueness of the sky and redness of sunsets resulting from light

of short wavelengths being scattered most by the atmosphere, or the color of grass resulting from its absorbing light of both shorter and longer wavelengths while reflecting the intermediate green. Electromagnetic waves with different wavelengths have different effects on the human body. Some pass through the body with little effect, some tan or injure the skin, and some are absorbed in different amounts by internal organs (sometimes injuring cells).
http://www.project2061.org/tools/benchol/ch4/ch4.htm#Motion_9_12

Students should now learn how well the principle of universal gravitation explains the architecture of the universe and much that happens on the earth. The principle will become familiar from many different examples (star formation, tides, comet orbits, etc.) and from the study of the history leading to this unification of earth and sky. The "inversely proportional to the square" aspect is not a high priority for literacy. Much more important is escaping the common adult misconceptions that the earth's gravity does not extend beyond its atmosphere or that it is caused by the atmosphere.

Study of the nature of electric and magnetic forces should be joined to the study of the atom. What is likely to surprise many students is how much more powerful electromagnetic forces are than the gravitational forces, which are negligible on an atomic scale. Some students may have trouble seeing mechanical forces, such as pushing on an object with a stick, as being produced by electric charges on the atomic scale. It may help for them to recognize that the electric forces they do observe commonly (such as "static cling") result from extremely slight imbalances of electric charges. As students come to believe in the action/reaction principle, they will expect forces to be mutual.
http://www.project2061.org/tools/benchol/ch4/ch4.htm#ForcesOfNature_9_12

Life Sciences

Two aims dominate at this level. One is to advance student understanding of why diversity within and among species is important. The other is to take the study of diversity and similarity to the molecular level. Students can learn that it is possible to infer relatedness among organisms from DNA or protein sequences. An investigation of the DNA-fingerprinting controversy may provide an interesting way to approach the question of the nature and validity of molecular evidence.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#DiversityOfLife_9_12

DNA provides for both the continuity of traits from one generation to the next and the variation that in time can lead to differences within a species and to entirely new species. Understanding DNA makes possible an explanation of such phenomena as the similarities and differences between parents and offspring, hereditary diseases, and the evolution of new species. This understanding also makes it possible for scientists to manipulate genes and thereby create new combinations of traits and new varieties of organisms.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Heredity_9_12

The individual cell can be considered as a system itself and as part of larger systems, sometimes as part of a multicellular organism, always as part of an ecosystem. The cell membrane serves as a boundary between the cell and its environment, containing for its own use the proteins it makes, equipment to make them, and stockpiles of fuel. Students should be asked to consider the variety of functions cells serve in the organism and how needed materials and information get to and from the cells. It may help students to understand the interdependency of cells if they think of an organism as a community of cells, each of which has some common tasks and some special jobs.

The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into the biochemical details. It is sufficient for students to know that the molecules involved are different configurations of a relatively few kinds of amino acids, and that the different shapes of the molecules influence what they do.

Students should acquire a general picture of the functions of the cell and know that the cell has specialized parts that perform these functions. This can be accomplished without many technical terms. Emphasizing vocabulary can impede understanding and take the fun out of science. Discussion of what needs to be done in the cell is much more important than identifying or naming the parts that do it. For example, students should know that cells have certain parts that oxidize sugar to release energy and parts to stitch protein chains together according to instructions; but they don't need to remember that one type of part is a mitochondrion and the other a ribosome, or which is which.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#Cells_9_12

The concept of an ecosystem should bring coherence to the complex array of relationships among organisms and environments that students have encountered. Students' growing understanding of systems in general can suggest and reinforce characteristics of ecosystems—interdependence of parts, feedback, oscillation, inputs, and outputs. Stability and change in ecosystems can be considered in terms of variables such as population size, number and kinds of species, and productivity.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#InterdependenceOfLife_9_12

Now students have a sufficient grasp of atoms and molecules to link the conservation of matter with the flow of energy in living systems. Energy can be accounted for by thinking of it as being stored in molecular configurations constituted during photosynthesis and released during oxidation. Although there is no need to account for all the energy, students should observe heat generated by consumers and decomposers. Discussions of ecosystems can both contribute to and be reinforced by students' understanding of the systems concept in general. The difficulty of predicting the consequences of human tinkering with ecosystems can be illustrated with examples such as the ill-considered fireprevention efforts in national forests.

This level is also a time to ask what this knowledge of the flow of matter and energy through living systems suggests for human beings. Issues such as the use of fossil fuels and the recycling of matter and energy are important enough to pay considerable attention to in high school.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#FlowOfMatterAndEnergy_9_12

Knowing what **biological change over time** [**evolutionary change**] is and how it played out over geological time, students can now turn to its mechanism. They need to shift from thinking in terms of selection of individuals with a trait to changing proportions of a trait in populations. Familiarity with artificial selection, coming from studies of pedigrees and their own experiments, can be applied to natural systems, in which selection occurs because of environmental conditions. Students' understanding of radioactivity makes it possible for them to comprehend isotopic dating techniques used to determine the actual age of fossils and hence to appreciate that sufficient time may have elapsed for successive changes to have accumulated. Knowledge of DNA contributes to the evidence for **organisms having changed over time** [**life having evolved**] from common ancestors and provides a plausible mechanism for the origin of new traits.

[**History should not be overlooked. Learning about Darwin and what led him to the concept of evolution illustrates the interacting roles of evidence and theory in scientific inquiry. Moreover, the concept of evolution provided a framework for organizing new as well as "old" biological knowledge into a coherent picture of life forms.**]

Finally there is the matter of public response. [**Opposition has come and continues to come from people whose interpretation of religious writings conflicts with the story of evolution.**] Schools need not avoid the issue altogether. Perhaps science courses can acknowledge the disagreement and concentrate on frankly presenting the scientific view. Even if students eventually choose not to believe the scientific story, they should be well informed about what the story is.
http://www.project2061.org/tools/benchol/ch5/ch5.htm#EvolutionOfLife_9_12