Lesson B-14

Cells II:
Cell Growth, Division, Differentiation, and Introduction to Reproduction

Overview:

In this lesson, students address the question: Where do cells come from? Observations will lead to their concluding that all cells, regardless of type, are formed through processes of cell division, cell growth, and cell differentiation; cells only come from a pre-existing cell, and cells are the basic unit of life. They are given the concept that DNA is the cell's "instructions" for these processes and how these instructions may be altered in the course of reproduction, leading to variation among siblings or litter mates. The lesson goes on to provide a cellular context for understanding the basis of cancer, stem cell research, and cloning.

Position in the Progression of Learning: From their observations that all biological tissues are comprised of cells (Lesson B-13) students, here, progress toward understanding the basic concepts that organisms develop via processes of cell division, cell growth, and cell differentiation and how DNA is the cell's "instructions." Students are also introduced to the concept of how cells (eggs and sperm) carry an organism from one generation to the next and introduce variation in the process. These ideas set the stage for further inquiry along multiple areas of life science.

Time Required:

Part 1. Cells and Their Differences (visual review of previous observations and posing questions, 20-30 minutes)
Part 2. Where Do Cells Come From? How Do They Become Different? (videos plus Q and A discussion, 50-60 minutes)
Part 3. Cells and Information (thought challenges with Q and A discussion and re-examination of video; 50-60 minutes)
Part 4. Cells and Societal Issues (Q and A discussion, 40-50 minutes; may be broken into shorter segments and/or extended as desired)

Practices: Students who demonstrate understanding can:

1. Use photomicrographs to illustrate how differences in the shape and structure of cells are related to the cell's function in the plants or animal body.

2. Present evidence showing that differences among cells have more to do with the function of the tissue than with the species from which the tissue was taken.

3. Cite evidence that cells only come from previously existing cells via a process of cell division.

4. Describe the processes by which cells attain the very different forms, structures, and functions that are seen in different tissues.

5. Model how skin and/or other tissue is repaired and/or replaced.

6. Cite evidence showing that individual plants/animals originate from a single cell and evidence for the origin of that cell.

7. Provide evidence that supports the conclusion that cells are the basic unit of life.

8. Give evidence supporting the idea that cells carry an abundance of "instructions," which are copied with each cell division, and are now identified as the chemical, DNA.

9. With the exception of identical twins, most siblings are quite different. Describe on the cellular level the cause behind this variation.

10. Describe how a given variety of fruit, a Macintosh apple for example, is maintained as a constant despite the fact that reproduction generally leads to variation. Demonstrate what is meant by cloning.

11. Describe how cancer is a cellular disease.

12. Address the questions: What are stem cells? What is the potential of stem cell research? What is the dilemma inhibiting stem cell research?

Required Background:

Lesson B-9, Vol. I. How Animals Move IV: Energy to Run the Body (Fundamentals of Anatomy and Physiology)
Lesson B-13, Cells I: Microscopes, Observations of Tissues, and the Cell Theory

Materials:

Part 1. Cells and Their Differences

Photomicrographs or prepared slides and means of projection or a monitor to review the cellular structure of different tissues. This should include mostly tissues that students are already familiar with from their previous observations (Lesson B-13) and should emphasize visual differences among cells of different tissues. Images may be downloaded from the Internet (Google: photomicrographs animal tissue/ also, photomicrographs plant tissues).

Part 2. Where Do Cells Come From? How Do They Become Different?

Video showing cell division of animal cells and plant cells (Google: mitosis)

Video showing fertilization and early development of sea urchins (Google: sea urchin fertilization embryology)

Pictures showing early development of human embryo (Google: human embryology)

Part 3. Cells and Information

No additional materials needed.

Teachable Moments:

Have microscope(s) and materials (as in Lesson B-13) out and available for viewing. Allowing students to do some previewing as they desire will draw students into this lesson.

Methods and Procedures:

Part 1. Cells and Their Differences

From previous studies (Lesson B-13) students should be experientially familiar with the fact that whatever biological tissue we examine, we find that it consists of cells of one sort or another. Use projected images, photomicrographs, or actual microscopic observations of tissues to review and emphasize this point.

As students are reviewing these pictures, ask, “Are all cells alike?” It is so conspicuous that cells are not alike that this may strike students as a totally dumb question. Nevertheless, bring them to focus on and describe, in their own words, some of the differences they note among cells, even those that are next to one another. For example, in an Elodea or moss leaf, they may observe that cells of the central midrib are quite different in shape from those between the midrib and the edge. When comparing the cells of different tissues of an animal, differences are even more profound. For example, skin cells are vastly different from muscle cells, from blood cells, from nerve cells, from cells along the inside surface of the intestine, and so on.

As students observe and describe such differences, ask: How do these differences relate to the role they are performing? For example, draw them to note that cells of a plant stem, which are like tubes, are adapted to carry water up and down the stem. Skin cells have a shape and structure that provide a protective layer over the body. Muscle cells have a shape and function that provide for contraction and hence movement, and so on. After two or three examples, turn it over to students. Ask them to consider the cells of an organ/tissue that they are looking at and the job of that organ/tissue. Ask them: How is the structure/shape of these cells adapted to perform that job?

> *NOTE:* Your exposure to learning about cells in a college biology course probably involved drawings of cells as simple ovals with all sorts of things inside to name, memorize, and identify: nucleus, mitochondria, vacuoles, etc. It may be tempting to do the same with your elementary students, but resist. Such an approach is not only dull and burdensome to most students; it also leads to a disconnect between what cells are and what they actually do in the body. Therefore, our approach here is different and it will lead students to a conceptual understanding of how a body (plant or animal) is made of multitudes of different sorts of cells, each performing a specific role or function.

Ask and have students reflect on the question: Where do we see the greatest differences among cells—among cells of different tissues, or among cells of different species? (In Lesson B-13, we noted, a major distinction between plant and animal cells, i.e., the presence or absence of cell walls; here, we wish to focus on different species within the same kingdom or phylum.)

Call students' attention to the experience they have had in looking at, for example, stem tissue of different plants. (Repeat such observations as necessary.) The conclusion will be that cells of stem tissue of one species look very much like those of another species. The same is found when comparing like tissues from different species of animals. For example, one would be hard pressed to distinguish the blood cells of a mouse from those of an elephant. So far as you can, have students verify this idea by examining photomicrographs of cells of the same tissue, liver for example, taken from different species of animals.

> *NOTE:* When one gets down to the level of DNA, which is the chemical genetic material within the nucleus of cells, chemical analysis does reveal differences among species and even between individuals.

In summary, beyond distinguishing animal cells from plant cells on the basis of their cell walls, it is difficult to impossible to distinguish one species from another by looking at cells. The great differences we have seen among various cells depend on the cell's role within the organism, e.g., skin, nerve, muscle, etc., not on the species, certain exceptions notwithstanding.

Part 2. Where Do Cells Come From? How Do They Become Different?

When students have gained the overall concept that all parts and organs of the body are comprised of cells, albeit with different forms and functions, pose questions such as: Where do cells come from? How do they get into the shapes to form the structures that they do? How do they take on the particular function they perform in a given organ? How does a body grow? Is the body making cells, or are cells making the body? Let students reflect, make suggestions, and debate their thoughts, as they will.

The question concerning whether the organism makes cells or cells make the organism is especially good for drawing students' interest and getting them involved in lively discussion. In all seriousness, scientists pursued this debate in the years following the announcement of the cell theory by Schleiden and Schwann in 1838, and it can be carried on with as much interest today. In fact, it becomes a chicken-or-egg argument, which has no real answer, but as students ponder and debate, challenge them to propose experimentation to determine what is really going on.

As students propose and debate the efficacy of various lines of experimentation, let them know that they are behaving exactly as scientists behaved in the late 1800s. The difference is that scientists of the 1800s spent many years trying out their ideas, experimenting, and making careful observations. Now, with modern technology and knowing what to do, we can show what they found in a video of a couple minutes. Show students a video of living cells undergoing division (Google: cell division living cells video).

> *NOTE:* In the first showings, keep the audio turned off. Bear in mind that our objective is have students see and experience what early scientists did, and draw their own conclusions. It is not to deluge them with technical terms of each phase nor even to name the process.

In view of the question, "Where do cells come from?" have students give the answer in terms of what they have just seen. Discussion will go as it will, but it should boil down to the conclusion that one cell gives rise to two by a process of CELL DIVISION. The two may divide and give rise to four, the four to eight, and so on. Stress that in every case where scientists traced an organism's development back its beginning, they found that development started with a single cell. Yes, every individual plant, animal or other sort of critter examined has been found to start its life as a single cell. (The origin of that cell will be considered later in this lesson.) All further cells of the organism were found to come from that cell via the process of cell division as just observed in the video. Scientists have never found less-than-cell particles coming together to make living cells, or cells being formed by any other process. Countless studies have been conducted since that time—consider the work involved in such studies—but the same conclusion remains: *Cells come from pre-existing cells via cell division.*

As students reflect on cell division, it will become self-evident that growth must be included along with cell division. If cells only divided in half, then in half again and again, they would rapidly diminish to nothing. Thus, have students reason that cells must take in food (and oxygen) for growth and energy. Yes, the food we eat, after digestion in the stomach and intestines, goes to feed our cells so that the cells can grow, divide, and carry on the more specific functions that they perform. Cells also excrete wastes. (We will address these aspects in more detail in Lesson B-15.)

Taking these two steps of division and growth together, help students visualize that there is an ongoing cycle. A cell grows; it divides; the two grow, divide, and so on. Have students reason that growth and division must always go on in tandem. A single cell does not grow indefinitely, nor can division occur more than a few times without growth. Thus, given food, water, air, and other suitable conditions, a single cell may grow into a large mass of cells. Indeed, the growth of our bodies may be thought of as the result of cell growth and cell division.

But hasten to add, a cell capable of division is a special kind of cell itself. Muscle cells, nerve cells, skin cells, liver cells, and every other kind of fully developed cells are incapable of division; that is, we never see them dividing. The cells that we do find dividing are always relatively simple cells without any features identifying them as belonging to one tissue or another. (These are known as stem cells and will be discussed later in this lesson.) This being the case, ask students, “What would be the result if cell growth and division were the only processes involved?”

They should recognize that the result would be just a big, formless blob of cells. Therefore, guide students to reason that there must be more involved. Cells must take on the shapes, structures, and functions necessary to develop into the sorts of cells we have been looking at in various tissues. In short, from their initial state following division, cells must become different; they must develop specifically to become a muscle cell, a skin cell, a bone cell, a nerve cell, or whatever is appropriate for their particular place in the body. This process of cells becoming different is called CELL DIFFERENTIATION. Have students note that this new word is not nearly as big or difficult as it looks. It is simply “-ation” added to the word “different.” The suffex “-ation” added to any word gives the meaning, “the process of.” Consider: classification, notification, consideration, continuation, and many other such words.

In summary, the growth and development of any body (plant, animal, or human) can be described on the microscopic level as resulting from these three processes: cell division, cell growth, and cell differentiation. But this is not the end of the lesson. A point of confusion that often arises is that students will tend to think of this as a rigid one-way sequence: cells divide, they grow, they differentiate, (period, end of story). Therefore, it will be important to point out and emphasize that all three processes may go on in tandem and continuously.

To describe it most simply: one cell divides to make two; both grow to some degree; then, one of the cells proceeds to differentiate while the other divides again. Now there are three cells, one differentiated cell and the two new cells. After some growth, one of the new cells proceeds to differentiate while the other divides again. Now there are four: two differentiated cells and the two new cells. Have students repeat this sequence several more times and observe the result. It is that any number of differentiated cells may be produced while still having cells capable of division.

Skin serves as a great example. Kids will be familiar with how, after a minor burn or scrape, old skin peels away and is replaced by new skin formed underneath. Use Q and A discussion to guide them to reason how this corresponds to what was just described. At the underside of the skin there are cells that divide, grow, divide, and grow in an unending cycle. On each round of the cycle, however, the cell toward the outside of the body differentiates to become a skin cell while the other divides again. Thus, there is a continuous production of skin from the inside out. Older skin cells on the outside continually die, get rubbed off, and are replaced by new cells from below. Hair and nails provide similar examples.

The same is true of blood. Red blood cells are incapable of division. But, your body maintains cells that do divide, grow, and differentiate to form new blood cells; thus, blood lost (as long as it is not too much) is soon replaced. Indeed, in all cases where the body repairs itself from injury, we can surmise that there are cells capable of division, growth, and differentiation such that repair/replacement occurs. Conversely, in cases where an injury is permanent—a lost arm or leg will not regrow, for example—we can surmise that there is an absence of cells that can divide, grow, and differentiate in this respect.

Again, the body's repair of any injury is indicative of cell division, growth, and differentiation. However, the human body (and that of other higher vertebrates) does not maintain dividing cells that will differentiate to replace muscle, brain, or regrow an arm or leg. We can blame the permanence of an injury on this "failing." Students may be intrigued to note that some animals, less complex than humans, have the capacity to regrow parts. There are certain worms, for example, that when cut two are capable of re-growing the missing end of each half.

Re-growing missing parts is even more common in plants. Indeed, many plants are propagated by cuttings. That is, sprigs cut from the top of the plant and placed in water form roots. Thus, one obtains a new plant from the cutting. What does this mean? (Think Time.) Again, it says that there are cells in the stem that remain capable of dividing, growing, and differentiating such that new roots are formed when the original roots are removed. Give kids plenty of Think Time to ponder the concept and ask questions.

Where Does the Process Start?

Draw students to reflect on the finding noted in the previous section: Through countless observations tracing the process of development back, scientists discovered that every individual, plant or animal, begins life as a single cell. Let students ponder: Where did that cell come from? Again, have students reflect on the sorts of experimentation and exacting observations that must have gone into finding the answer.

The discovery is that the female produces special cells (in her ovaries) we call egg cells. The male produces special cells (in his testes) called sperm cells. A sperm cell combines with an egg cell in a process called FERTILIZATION and the resulting cell is the first cell of the new "baby." You can add further details to the process as you see fit. The point to emphasize is that the idea that cells only come from pre-existing cells is not changed. Sperm cells come from pre-existing cells in the male testes; egg cells come from pre-exiting cells in the female ovaries, both via cell division and differentiation. The only unique thing involved is the combining of egg and sperm in fertilization. There are great videos showing fertilization and subsequent division and differentiation in sea urchins, which just happen to be a fantastic "guinea pig" for this purpose (Google: fertilization embryology sea urchin). You can also find any number of photographs showing various stages of development in humans (Google: human embryology photographs).

> NOTE: To be sure, the cell divisions leading to eggs and sperm are different from those leading to more body cells. In the formation of eggs and sperm the chromosome number is reduced by half, and in fertilization the halves from the male and female are combined again making a whole. However, getting into this tends to be more than young students can handle. Therefore, we omit it here in order to keep the attention on the central ideas of cell division, growth and differentiation.

Add that scientists have found this reproductive cycle of eggs, sperm, and fertilization in every species studied. Yes, plants, as well as animals, have male and female parts that produce eggs and sperm, which combine to produce the next generation. (Most plants and many lower animals may reproduce by cloning as well, as we will discuss later.)

Ponder with your students the awesomeness of what is really going on. Yes, the overall idea is embraced by three simple terms: cell division, cell growth, and cell differentiation. Yet how are these processes controlled and directed? Draw students to reflect: For a fertilized egg to develop into an individual, cell growth, division, and differentiation must be precisely regulated and directed every step of the way. The significance of these regulatory processes cannot be overemphasized. Cell growth, division, and differentiation must be regulated not only in general respects, but down to every detail, including producing the color of the hairs on the head. The mysteries of how this regulation is achieved promises to provide countless research challenges for the future.

A Cell Is the Basic Unit of Life

Ask students: Is there such a thing as a basic unit of life? With some reflection, students will answer, “Cells.” Ask them to support this view with arguments from their observations. Their argument(s) should include the facts that: Every living organism is comprised of one or more cells. The life of every organism begins with a living cell. Individual cells have the attributes of living things requiring food, water, and air, and are capable of reproducing themselves, i.e., cell division. Nothing less than a cell is seen to have all of these attributes.Yes, cells are commonly referred to as the basic unit of life.

Part 3. Cells and Information

Draw students to consider again the concept that a single cell (the fertilized egg) through processes of cell division, growth, and differentiation, grows into the whole animal (or plant) with all its parts perfectly formed and arranged (with few exceptions). Further, draw them to consider the implications of this observation. (Think Time.) How do the cells “know” just when and how many times to divide, how much to grow, and whether they should differentiate into muscle, bone, nerve, or other sorts of cells? Even more, how do the cells of a fertilized chicken egg “know” to arrange themselves to make a chicken and those of a fertilized human egg “know” to arrange themselves to make a human? Guide them in reasoning: There must be “instructions” within the cell that direct its development. It follows that the “instructions” must be copied and a copy given to each new cell in the course of cell division.

Show the video of cell division again, while asking the question: Can you see anything here that corresponds to something being copied and each cell getting a copy? It may take several viewings and a hint to focus on the chromosomes (the worm-like things in the middle) but students will see that they fit the bill.

Indeed, scientists have gone on to analyze the chemical makeup of chromosomes and found that entwined within them is a chemical, DNA, that has attributes of coded information. Further, the code is unique for each species. Even within a species, there are differences corresponding to the uniqueness of each individual. Thus, a DNA sample can be obtained from even a few cells and this can be sufficient to identify the individual, a fact commonly alluded to in detective programs.

Students have probably heard things such as “You look like your father,” or “You look like your mother.” The reference is often made to more particular features, like eyes, hair, etc., or put in terms of: “You’ve got (inherited) your mother’s/father’s ________.” How is this possible? Guide students in relating this to the egg, sperm, and fertilization.

Indeed, scientists have discovered that the DNA instructions are passed to and incorporated into the new baby by way of the egg, sperm, and fertilization. However, only half the DNA instructions from each parent are incorporated into each sperm/egg. As these two halves come together in fertilization, that first cell gets a full set of DNA instructions, but half from the mother and half from the father. Those DNA instructions are duplicated with each cell division thereafter. Thus, the offspring exhibits certain features of both parents.

However, there is some randomness in the "half" of the mother's DNA instructions that end up in a given egg. The same is true for the father's DNA instructions that go into a sperm cell. Therefore, the "halves" of DNA instructions that successive offspring get from each parent are seldom the same, leading to the fact that successive offspring are seldom identical. Probably the most significant difference is that any given sperm may carry DNA instructions for developing into a female, or DNA instructions for developing into a male. There is a 50/50 chance of either.

Students will often speculate that one might cross two different animals, a pig and a chicken, for example, and get a flying pig. The reality is that DNA instructions from the male and female, while they may be somewhat different, must still be able to fit together closely, and work in harmony. The DNA differences between two species are usually too great; there is a conflict of DNA instructions such that further cell divisions fail to occur.

The conspicuous exception to what we have been saying is identical twins. Investigating the origin of identical twins, scientists have discovered that they are derived from the same fertilized egg. After the very first division of the fertilized egg, the two cells come apart and each goes on to develop into a full individual. Since they are derived from the same fertilized egg, each has exactly the same DNA instructions; therefore, they come out the same. Contrast this with the separation and recombination of DNA instructions that occur in the formation of eggs and sperm and their recombination in fertilization.

Summarize and conclude this section by reiterating that scientists have, thus-far, found the cellular "instruction book," i.e., the DNA that guides development. They have further unraveled the mechanism by which certain segments of DNA (genes) result in certain effects, e.g., certain genetic diseases (Google: Genetic diseases). Still, they have barely scratched the surface in understanding the mechanisms by which cells are guided to differentiate to form one part of the body or one organ rather than another. Untold opportunities for further discovery await students choosing to enter this area of science.

NOTE: It may be tempting in this section to go into much more detail concerning genetics, DNA replication and transcription, and so on, but bear in mind that students can be overwhelmed by too much information. The objective here is to convey the concepts as simply as possible and save further details for later lessons, or allow further details to emerge from students' questions.

Part 4. Cells and Societal Issues

Cloning

Ask: Is the process we have described involving eggs, sperm, and fertilization the only way biological organisms have of reproducing? If students are not already familiar with it, point out how one can take a sprig from a mint or willow, place it in water, and observe it forming roots. (This may easily be demonstrated, although it takes a week or so for roots to form.) Many plants are commonly propagated in this manner. Many propagate themselves in a similar manner in the course of their natural life cycle. Consider strawberry or spider-plant runners, for example (Google: strawberry runners photo). Many lower animals may reproduce similarly. Consider the budding of hydra or experiments with Planarian worms, for example (Google: hydra budding video/ Planarian experiments video)

Draw students to consider the DNA instructions for these organisms and ask: Is there any change in the DNA instructions occurring between "parent" and offspring seen here? Have students revisit the fact that variation between parents and offspring and among offspring occurs as a result of segregation of DNA instructions in the formation of eggs and sperm and its recombination in fertilization. Here, the "offspring" result from a continuation of basic cell divisions. Only differentiation has been reprogrammed; the basic DNA instructions remain unchanged. Therefore, all the offspring resulting from ASEXUAL reproduction (reproduction without involvement of eggs, sperm, and fertilization) have exactly the same DNA instructions; and those DNA instructions are exactly the same as the "parent." They are said to be GENETICALLY identical. All the offspring from such reproduction are said to be a CLONE. Said another way, all members of a clone are genetically identical; they all have exactly the same DNA instructions.

Most of the fruits we buy on the market are actually clones. For example, Macintosh apple trees have been reproduced asexually so that every Macintosh apple is genetically identical to every other although they come from countless different trees. (Students may choose to investigate the many techniques that are used commercially for propagating plants asexually.)

Higher animals (vertebrates) do not naturally reproduce asexually. However, in the last few decades scientists have gradually learned the techniques to clone many of our domestic animals: sheep, pigs, cattle, etc. The tricky point is that this means we have the technological capability to clone humans as well. Should we do so? If so, who gets cloned, and who does the cloning? For what purpose? Let students ponder and discuss the social issues involved.

Cancer

All forms of cancer are basically a malfunction of the mechanisms (whatever they are) that control and determine normal cell division, growth, and differentiation. (Remind students that cancer is a noninfectious disease.) The "malfunction" causes cells to get "jammed" in the growth-division cycle; they continue to divide and grow when they shouldn't, and they fail to differentiate, as they should. Thus, instead of differentiating properly to form replacement cells for the organ, they just form a mass of cells that only divide and grow more and more until they finally crowd out and stop the functioning of the organ(s) where they are located. Treatments such as radiation and chemotherapy are designed to kill off, or at least stop, the division of these wayward cells. The problem is that these treatments tend to damage or inhibit normal cells as well; hence hair loss from chemotherapy. A much better treatment would lie in being able to repair the malfunction of those wayward cells or have them die of their own accord; such solutions await discoveries by future scientists.

Stem Cells

Students have probably heard of stem cells or stem cell research, but without much understanding. Explain that STEM CELLS is the name given to those cells that maintain the capacity to divide, grow, and most importantly, potentially differentiate into all the organs/tissues of the body. The concept behind stem cell research is: If we can discover the systems that lead those cells to differentiate in one way verses another, we will have the means of replacing lost or defective body parts/organs. We could enable an amputee to regrow an arm or a leg. We could enable a person to regrow a defective organ and thus cure all sorts of noninfectious diseases, or enable a blind person to regrow eyes, and so on. Students will have fun musing and suggesting other possibilities; encourage them to do so. The list of possibilities that they may record will be endless.

In order to conduct such research, scientists need a source of stem cells to work with. The problem is that along the course of development most cells loose the capacity to differentiate in multiple directions. To date, the source of the best stem cells—those that have the most capacity to differentiate toward forming any tissue or organ—is from very early embryos. This makes sense since those are the cells that do go on to form all parts of the body. But obtaining such cells means sacrificing that early embryo. The ethical dilemma is self-evident.

> *NOTE*: An extensively used practice for couples who have difficulty conceiving is in-vitro fertilization. Egg cells are taken from the woman, sperm cells are taken from the man and they are placed together in a dish so that fertilization will occur. As embryos begin to form, one of them is implanted in the mother's uterus; the others are frozen or disposed of according to the wishes of the couple. It is these embryos, which

would be disposed of, that scientists wish to use as a source of stem cells to conduct research. Does this make an ethical difference?

Happily, scientists have recently discovered that stem cell may be obtained from other body tissues, making the use of early embryos a moot point.

Questions/Discussion/Activities to Review, Reinforce, Expand, and Assess Learning:

Students should record in their science notebooks:

a) labeled diagrams illustrating cell division, growth, and differentiation into one or more specific cell types that have been observed
b) labeled diagrams illustrating how skin continually replaces itself
c) labeled diagrams and descriptions illustrating production of eggs, sperm, and the origin of a new individual (of any species)
d) labeled diagrams and descriptions showing how/why siblings are usually different, but identical twins occasionally occur
e) a paragraph describing what stem cells are and their significance
f) a statement contrasting cancer with normal cell differentiation
g) a paragraph describing mysteries that remain in cell biology

Have students display the concept(s) they have gained in this lesson in terms of: a general pattern; a cause and effect sequence; stability and change; flows and cycles; structure and function; scale, proportion, and quantity.

Make posters or models illustrating cell division, growth, and differentiation. Particularly, illustrate how cells derived from the same fertilized egg cell differentiate into all organs and tissues of the body.

Facilitate students finding, observing, and contrasting photomicrographs of different cell types, and watching videos of cell division and the development and differentiation of a sea urchin egg (Google: sea urchin development video).

Have students individually pursue the cellular makeup of an organ/tissue of their choice and give a show-and-tell describing how that cellular structure enables the organ/tissue to do its job. (This may also involve written assignments.)

Have students construct models illustrating cell division, growth, and differentiation. Give show-and-tells accordingly.

Contrast the origin of unlike siblings with that of identical twins.

Investigate, discuss, and pursue methods of cloning used in agriculture, e.g., the rooting of cuttings and grafting.

Have students make models or illustrations depicting the differences between cells found in different tissues. Give show-and-tells accordingly.

In small groups, pose and discuss questions such as:

- Cells are commonly referred to as the fundamental unit of life. What is the evidence supporting this view?
- How does one generation of an organism beget the next? (Describe/discuss on the cellular level processes/steps involved.)
- What is the evidence that cells contain information/instructions? What is the chemical nature of those instructions? What observations suggest that those instructions are copied with each cell division?
- What possibilities would be opened up if we fully understood how cell differentiation is controlled?
- What are stem cells and what is the aim of stem cell research?
- What are the causes behind siblings being different and identical twins being the same?
- What is involved in cloning? Why does it result in genetically identical individuals?
- What is the distinction between cancerous and normal cells?

To Parents and Others Providing Support:

Help children use the Internet to find and view photomicrographs of different plant and animal tissues. Observe and discuss how the cells of each tissue are specialized to perform a particular job. Discuss how each cell reached its specialized state through growth and differentiation.

Help children use the Internet to find and download videos showing cell division, sea urchin embryology, and stages of human embryology.

Discuss what the processes of cell division, growth, and differentiation imply regarding cells carrying "instructions." Relate those instructions to DNA and vice versa.

In regard to cancer, discuss how the disease is a malfunction of normal cell processes.

At a fruit market, discuss how particular varieties are maintained through cloning rather than the mating of a male and female.

Books for Correlated Reading:

Burnie, David. *The Kingfisher Nature Encyclopedia*. Kingfisher, 2010. (See especially Part 2, the Living World.)

Cohen, Marina. *Cells*. Crabtree, 2009.

Johnson, Rebecca L. *Mighty Animal Cells* (Microquests). Millbrook Press, 2008.

__________. *Powerful Plant Cells* (Microquests). Millbrook Press, 2008.

Rogers, Kirsteen, et al. *The Usborne Science Encyclopedia.* Usborne, 2011. (See especially sections on cells.)

Somervill. Barbara A. *Animal Cells and Life Processes* (Investigating Cells). Heinemann, 2010.

__________. *Cells and Disease* (Investigating Cells). Heinemann. 2010.

__________. *Plant Cells and Life Processes* (Investigating Cells). Heinemann, 2010.

Taylor, Charles. *The Kingfisher Science Encyclopedia*. Kingfisher, 2011. (See especially Chapter 3.)