Lesson B-14

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

Overview:

In this lesson, we will move from the observation of the cellular nature of tissues to questioning: Where do cells come from? How does an organism grow? How do different organs and parts of the body develop? Students will discover that the answers to these questions hinge on three cellular processes: cell growth, cell division, and cell differentiation. Again, we will keep this on a very general, observable level that will instill important concepts without overwhelming students with details and terminology. The basic understanding gained will not only give students greater appreciation for their own bodies; it will provide insights regarding cancer, the stem cell controversy, and other social issues, as well as giving them a peek into the vast world of cell biology still to be explored.

Position in the Progression of Learning: In the previous lesson (Lesson B-13) students learned to use a microscope and gained experience by examining various biological tissues. They discovered that all tissues (both plant and animal) are comprised of repeating units called cells. This finding introduced them to the cell theory. Students further observed that the shape and structure of cells, even in the same organism, differed greatly from one tissue to another. In this lesson, students will pursue the same line of investigation further to learn that every cell is derived from a pre-exsiting cell through a process of cell division, and then takes on specialized features through a processes of growth and differentiation. This provides a conceptual understanding of growth, development, and reproduction and sets the stage for pursuing a more sophisticated understanding concerning the multitude of questions in these areas.

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 challenge 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 the differences in shape and structure of cells of different tissues relate to the function of those cells within the 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 is taken.

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

4. Describe how cells attain the very different forms, structures, and functions as seen in different tissues.

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

6. Use observation on the cellular level to describe how a new individual (of any species) comes into being.

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 information and that information is carried in the chromosomes.

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

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
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:

Having microscope(s) and materials (as in Lesson B-13) out and available for viewing and 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 provides a protective layer over the body. Muscle cells have a shape and function that provides 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 desist. Such an approach is not only dull and burdensome to most students; it also leads to a total disconnect between what cells are and what they actually do in the body. Therefore, our approach here is totally different and it will lead students to a conceptual understanding of how the 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., 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 (or repeat again as necessary). The conclusion will be that the stem tissue of one species looks the same or very similar to stem tissue of another species, and the same goes for other tissues. When it comes to different tissues, however, the differences are too evident to need mention.

Turning to photomicrographs of animal tissues, have students note that the species, from which the tissue is taken, is seldom given. This is because between species there is little or no distinction in the appearance of cells from a given tissue. For example, muscle cells of a mouse look the same as muscle cells of a human. The same goes for other tissues. One would be hard pressed to distinguish the blood cells of a mouse from those of an elephant. A larger animal (or plant) does not have larger cells; it only has more of them.

> *NOTE:* Of course, when one gets down to the level of DNA, which is the genetic material within the nucleus of cells, chemical analysis does reveal differences among species and even among individuals. However, at this stage of introduction to cells, let students be impressed from their observations that cells of one species (comparing

tissue for tissue) do not differ markedly from cells of another species, at least within the same kingdom.

In summary, the overall concept that should sink in for students—allow think time for it to do so—is that the body is made up of various organs and organ systems. When we observe the tissues that comprise the different organs on a microscopic level, we find that they are all comprised of cells, but the cells of one tissue differ markedly from those in another tissue. The differences among cells pertains to the job they are doing, i.e., the function they are performing. These functions, hence the cells that perform them, are a constant across species within the kingdom. Therefore, cells of a given tissue are very similar despite being from different species. Assign students to find examples and give show-and-tells that will illustrate and emphasize this point. It can hardly be overstressed.

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 and structures that they do? How do they take on the particular function that 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 questions concerning whether the organism makes cells or cells make the organism are 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. Only these scientists took years to make the exacting observations and conduct the experimentation required and we now have the answers from their work. In short, it led to the conclusion that all cells originate from a pre-existing cell by a process of cell division. One cell divides to make two; these two may divide to make four, these four to make eight, etc. We never find less-than-cell particles coming together to make living cells. It is always a process of cell division as can be seen under a microscope. Find and show videos of dividing plant and/or animal cells (Google: cell division living cells video).

NOTE: Videos showing cell division will display details concerning the condensation of chromosomes and their movements with a sound track describing and naming the phases of mitoses (the technical word associated with cell division). Silence the sound track for the time being. Keep in mind that the objective, at this stage, is to have students grasp the idea that cells originate by the division of a cell that is already there. The details will only serve to overwhelm and can be easily saved for later. Or, students who wish may pursue the topic as independent studies.

Second, guide students to reason that growth must be included along with cell division. Division alone would rapidly diminish cells toward nothing. Instruct students that cells 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 together, help students visualize that there is an ongoing cycle of cell division and cell growth. 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 the 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 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 with 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 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 into 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. What happens next? Have students note that this means an organism can produce any number of differentiated cells, which don't divide, while still maintaining cells that divide to produce new cells.

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.

Kids will be intrigued to note that many animals, less complex than humans, have the capacity to regrow parts. There are certain worms, for example, that when cut in half, each half is capable of re-growing the missing end. This means that their bodies maintain cells capable of division, growth, and differentiation.

Again, the body's repair of any injury is indicative of cell division, growth, and differentiation in action. However, the human body (and 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." Some students may note that there are lower animals that do not have this "failing." They can regrow tails and sometimes other missing parts. Yes! This should be taken to mean that their bodies maintain cells with the full capacity to divide, grow, and differentiate to replace the whole of the missing part. 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. It may also be helpful to use guided imagery to help them visualize the process occurring, their skin repairing itself from a scrape, for example. Some students may undertake constructing a model that will illustrate the process.

Where Does the Process Start in the Growth of a Baby?

Draw students to consider: If the body is comprised of cells and cells only come from pre-existing cells, where does the growth of a baby, or an embryo of any species, start? Again, let students ponder the question and suggest means to find out. Let them know that scientists likewise spent years making the observations, tracing development back further and further to its beginning. The finding was (and remains with current observations) that every organism, plant, animal, human, or other, begins its life as a single cell. That single cell is formed from the union of two cells: a sperm cell from the male, and an egg cell from the female. This union of egg and sperm cells is FERTILIZATION. The egg cell is said to be fertilized by the sperm cell. (Reproduction by cloning is a separate matter that will be considered later in this lesson.)

The fertilized egg, the first cell of the new individual, goes on through cell division, growth, and differentiation, to form the complete individual of whatever species it is. 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).

Students may ask: Where do eggs and sperm come from? Again it is through cell growth, division, and differentiation. In the male (testes) cell divisions and differentiation lead to production of sperm cells. In the female (ovaries) they lead to egg cells.

Ponder with your students how this reproductive cycle is consistent with the central idea that cells only come from pre-existing cells. No exceptions to this rule have been found. Likewise ponder how this cycle of reproduction is common to all living things despite their vast differences in outward appearance.

Most of all, ponder the awesomeness of what is really going on. Yes, the overall idea is embraced by three simple terms: cell growth, cell division, 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 at every step of the way. The significance of these regulatory processes can not 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.

NOTE: It is conspicuous that I have left out all sorts of detail regarding meiosis, genetics, and other terminology. This is very intentional. I find it more prudent to stay with and reinforce the central concept of cell division, growth, and differentiation. Introducing detail and terminology at this stage does more to distract than help. Of course, many further questions will come up. Address them as you see fit.

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 suggest 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, air, and are capable of reproducing themselves, i.e., cell division. Nothing less than a cell is seen to have all of these attributes. Let students know that they are correct in their thinking. Scientists commonly refer to cells as the basic unit of life.

Part 3. Cells and Information

So far as possible re-emphasize and convey the awesomeness of the idea that a single cell, through the seemingly simple processes of cell division, growth, and differentiation, can grow into all the parts and organs of an individual of its particular kind (species). The underlying questions, whether expressed or not, are: How are cell division, growth, and differentiation controlled and directed in such a way that everything turns out right, i.e., producing normal offspring for the species in question (with few exceptions)? What directs and controls a cell in one place to form a skin cell rather than a bone cell, for example? What directs cells in one area to form an arm and cells in another area to form a leg? What controls and directs some to form an eye, while others nearby form an ear? Have students look at their own features and give further examples of how cells "here" formed ___________, while cells "there" formed ___________.

As students reflect on these "How?" questions, draw them to consider that there must be instructions of sorts. That is: In that single cell, the fertilized egg, there must be mechanisms and systems that guide the cells in their growth, division, and differentiation such that they develop into a human as opposed to a chicken, for example. Invite students to give further examples illustrating this concept. Drawing on students' personal experiences, emphasize the point again: Each species reproduces its kind. There is, to be sure, some variation among the puppies of a dog's litter, but a dog always produces puppies, never kittens. The same argument can be made for every other species.

Indeed, the information is even more precise than just determining the general features of the species. Have students consider how they have certain features of their father and certain features of their mother, as well as unique features of their own. How can we explain this? With Q and A discussion, guide students in reasoning that the egg cell carries information to guide development into a likeness of the mother, from which it came. The sperm, likewise, carries information to guide development into a likeness of the father, from which it came. The result of the two sets of information combined in the fertilized egg leads to some features of each parent, a blend of each, plus some unique features not observed in either parent.

Ask students to reflect on: What is the nature of that information that instructs cells to grow, divide, and differentiate as they should? It obviously cannot be written instructions and/or maps as we usually think of information. To make the distinction, the information carried in cells is referred to as GENETIC INFORMATION.

Guide students in reasoning how there is a logical necessity for genetic information, whatever it is, to be copied and copies distributed to each new cell upon division. Reshow the video of cell division and ask students if they see anything that is suggestive of material being copied and copies distributed to each of the resulting cells. Yes! Chromosomes are the logical candidate, and scientists spent many years investigating chromosomes through direct observation, genetic experimentation, and chemical analysis.

All of this work culminated in the mid 1900s with the discovery that genetic information is encoded in DNA molecules that are entwined in the chromosomes and carried within the nucleus of each cell. In cell division, the DNA is copied and a copy is passed to each cell as we see in the movement of chromosomes in cell division. Scientists went on to further discover how the information encoded in DNA is translated into the making of specific molecules (enzymes) essential in life processes. However, we still know almost nothing concerning how the basic processes of cell divisions and differentiation are controlled and regulated to guide development of the fertilized egg into an offspring of the given species, much less the more detailed features. Solving these puzzles will provide opportunities of exploration for many scientists in the future.

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 them to emerge from students' questions.

Part 4. Cells and Societal Issues

Variation among offspring, identical twins, and cloning

Return to the concept that offspring are produced through the union of egg and sperm in fertilization. While all eggs carry genetic information that will guide development toward, "looking like the parent from which it comes," it turns out that genetic information regarding details differs from one egg to the next. Some eggs may carry information for blue eyes, another for brown eyes, for example, and the same idea holds for the details of countless additional features. The same is true for sperm cells. One may add, "even more so." Half the sperm cells carry genetic information to become a male; the other half, female. The result of these genetic differences among eggs and sperm is that brothers and sisters seldom look exactly alike. (You may note here that if genetic information carried by egg and sperm is too different, e.g., from different species, the "tug-of-war" between the development into one thing versus another cannot be compromised and the cells do not divide, much less differentiate.)

The obvious exception to brothers and sisters being distinct is identical twins. Investigating the origin of identical twins, scientists discovered that they are derived from the same fertilized egg. After the very first division, the two cells come apart for some reason. Each now separate cell goes on to develop into a full individual. Since they are derived from the same egg and sperm cell, however, they carry the same genetic information; hence, they are identical twins.

Pause and ask students if they glean the most significant point here. (Think Time.) It is that variation among individuals comes about because of differences in genetic information. In turn, the differences in genetic information are the result of eggs and sperm carrying somewhat different selections of genetic information from the female and male. In short, variation is the result of the sexual reproductive process: eggs, sperm, and fertilization.

If/when individuals come about without this sexual process, their genetic information is the same, and offspring are identical in terms of genetic information. Reproduction without the sexual process is commonplace in many plants. Consider how many plants reproduce by means of runners, the modified stems that arch or creep from the parent and form new plants along the way. Crabgrass, strawberries, and spider plants are examples. The multiple offspring that carry identical genetic information are called a CLONE. The process is known as CLONING. Humans take advantage of this capacity to reproduce particular varieties of fruits. All Macintosh apples, for example, are really a clone. The same can be said for all other specific varieties of apples and other fruits.

A hands-on demonstration is the following: Take fresh sprigs of mint or twigs of willow, which are notorious for their rooting ability, and place them in water. Within a week or so, students will observe that roots are beginning to protrude from the cut stem. After roots are well developed, another week or so, the cutting may be placed in soil and kept well watered to produce a new plant.

Fungi, some simple animals such as hydra, and protozoa also clone themselves in the course of their natural life cycles. Finally, in the last few decades we 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? For what purpose?

Cancer

All forms of cancer are basically a malfunction of the mechanisms (whatever they are) that control and determine normal division, growth, and differentiation of cells. (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 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 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, differentiate. (Cancer cells grow and divide but they don't differentiate. Mature differentiated cells don't divide.) The concept and objective behind stem cell research is: If we can discover what makes those cells differentiate as they do in the healthy body, 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, 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.

The problem and controversy concerning stem cell research is that to conduct such research, scientists obviously need stem cells to work with. 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 does mean 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.

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 specific cell types that have been observed
b) labeled diagrams illustrating how skin continually replaces itself
c) labeled diagrams and description illustrating production of eggs, sperm, and the origin of a new individual (of any species)
d) labeled diagrams and description 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 conceive and display the concept(s) they have gained in this lesson as a general pattern of development extending from egg, through fertilization, to early embryology. Describe the events in terms of: cause and effect; information systems; structure and function.

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, watching videos of cell division, and 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., rooting 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 referred to as the fundamental unit of life. Explain why.
- Name, describe, and discuss the cell processes involved in going from parents of one generation to offspring of the next. Break this down so that students take turns describing, "What comes next?"
- Discuss what observations of cell division, growth, and differentiation imply concerning the cell's contained genetic information. What observations are suggestive of replication and transfer of genetic information to each cell in the division process?
- What possibilities would be opened up if we could fully understand the factors responsible for cell differentiation?
- What is the role and importance of stem cells in conducting research regarding cell differentiation?
- What happens at the cellular level that results in identical twins?
- What is involved in cloning? Why does it result in genetically identical individuals?
- Contrast cancer with normal cell division, growth, and differentiation.

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 genetic information. Discuss the fine detail of that information as portrayed by particular characteristics that have been passed down in your family.

With reference 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.

Re: Framework's Principles and Next Generation Science Standards (NGSS)

The fundamental concept of how cell division, growth, and differentiation underlie the growth and development of all organisms is a key principle underlying all life sciences. The same may be said for the concept of reproduction hinging on the union of an egg and sperm. Students of any age almost invariable have personal questions and concerns in this area, to say nothing of society. How it sets the stage for further investigation is self-evident, as is meeting the criteria for a *Core Idea*.

Conduction and follow-up of the lesson will readily involve students in *Practices*: a, b, c, d, f, and g. *Crosscutting Concepts* that come into the picture will be: a, b, d, and g. The lesson provides fundamental principles underlying numerous NGSS.

Books for Correlated Reading:

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