# Living Earth Unit 5
## Structure, Function, and Growth: From Cells to Organisms

**Background for Teachers and Instructional Suggestions**

Before starting this instructional segment, teachers should review the characteristics of life with their students. For example, working in groups, student can sort pictures of living and non-living things into the two categories and defend where they put each item. The samples would include things such as plants, insects, mammals, electronics, plastic toys, as well as unusual examples and outliers such as a sponge, rock, lichen, tunicates, snakeskin, molds, and/or a skeleton. Groups of students come to a consensus as to what goes in each category and why. After presenting their thinking to the entire class and listening to the thinking of their classmates, students can re-sort the most debated items. Groups would discuss the similarities and differences all of the living organisms had in common. Having students brainstorm the characteristics of life and how in most living organisms these characteristics are linked by ***systems and systems models*** can be an engaging way to start this instructional segment. It is also expected that the students will build on their **models** developed during middle school of cells and bodies as systems (*MS-LS1-1, MS-LS1-2, MS-LS1-3*). Students should also be able to explain the role of genes and how changes in them (mutations) can cause a change in the proteins a cell constructs (*MS-LS3-1, MS-LS3-2*). Formative assessments at the beginning of this instructional segment will help teachers determine what level of detail they will need to revisit in order to help students succeed during this instructional segment.

As George Beadle (a biologist in the early twentieth century) said, “one ought to be able to discover what genes do by making them defective.” Students can start with the idea that DNA holds the information necessary for all phenotypes of the organism but not all of this information is necessary at all times or in all cells (analogous to a library that holds lots of books arranged by subject, but only some of those books are checked out at certain times). Often the mapping of genes to their resultant phenotype is done by looking at mutations, if a changed phenotype results the mutation can be

linked to that phenotype. Mutation gene maps for model organisms are available and students can refer to these as they look at mutated phenotypes. Identifying the gene and related nucleotide sequence provides the code that is translated from nucleotides to amino acids. Illustrating how the codon table is a code for translation of the nucleotide language (DNA and RNA) to the amino acid language (proteins) can help students see the connection between nucleotides and proteins. The line-up of the nucleotides on the DNA strand is the template for the order of the amino acids which then determines which specific protein gets made. It is not necessary at this point to provide all the details of the translation process, or have the students memorize a codon table or map out metabolic pathways, however, it is important for students to make the connection between DNA, gene expression, and proteins. Historically, most of these connections were made by looking at mutants, and now students can observe this by looking at loss of function in strains of bacteria[1] or mutant strains of quick growing plants[2]. Students can then gather **evidence** to create an **explanation** for the importance of the connection between DNA and proteins and how it connects to the physical features of an organism. An extension of this idea can involve **planning and carrying out investigations** to determine if mutants can grow in varying environments (this can then be referred back to when students look at variations within populations and effects of environment on individuals within populations instructional segment 3) (*Note*: gathering data and analysis electronically in the cloud allows students and teachers to easily refer back to these investigations).

The next step would be to move from the micro level to a more macro level by looking at ***systems*** within organisms and tying that back to DNA, proteins and mutations within those that might have an effect on one part of an organism but not on another part. One way to demonstrate this would be to build **models** that show how a

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[1] It is possible to buy safe bacteria strains from many biological supply companies that are resistant to antibiotics and compare to ones that are not or ones that grow in the presence of lactose and ones that can't breakdown lactose and therefore change color.

[2] A search on the web should provide links to companies that maintain normal and mutant seed stocks.

system works then “mutate” part of it and observe the effects. For example, a model could be built of the respiratory system in mammals/humans showing how the movement of the diaphragm affects the pressure in the chest cavity allowing for our lungs to push out or take in air. Then if one “lung” is non-functional what happens?

A connection on how cells work together in tissues, organs, and finally organ ***systems*** can be shown by looking at how homeostasis occurs in organisms. One of the important characteristics of life is the ability to maintain homeostasis from the cellular level to the whole organism. This means that despite changes in the environment an organism has the ability to maintain certain internal chemical and physical states. This happens because an organism has the ability to respond to stimuli. The significance is in the functioning of proteins especially when looking at enzymes, which must have stable environments in order to function correctly. Enzymes usually have a fairly narrow range within their environment in which they can work. For multicellular organisms, the first line of regulation is through their skin or outer layers (epithelium) which respond to stimuli in the environment. An example in mammals is that most have a constant internal temperature but when it is hot they might sweat or pant and when it is cold they might shiver and their skin is the first place the body recognized the change in temperature. **Investigations** that demonstrate responding to stimuli is one way this could be tested, and they could be an extension of experiments performed previously on mutants or can be a different experiment. Using planarians placed in light versus dark conditions or how plants grown in the dark will grow taller as they search for light are two classic hands on labs demonstrating response to stimuli. The students can then explore other conditions to observe responses by the organism. Students may not comprehend the biological reasons (i.e., photosensitivity, hormone distribution, avoidance etc.) for the results. However, they will be able to predict outcomes of the response of the planarians or the plants as the experiments are repeated.

One of the characteristics of life is the ability to grow, whether as a single cell or as a multi-cellular organism. In the 1860’s Rudolf Virchow proposed that new cells arose from pre-existing cells. As the ability to view cells under microscopes improved in the late 1800’s evidence gathered from looking at cells supported Virchow’s claim. In order to go from a single cell (fertilized egg) to a multicellular organism, cells need to produce

more cells. This is also true for unicellular organisms when they are ready to reproduce and again make more cells. The process in both cases must involve a true copying of the information from the parent cell to the daughter cells. Cells, just like organisms have a life cycle referred to as the cell cycle. The cell cycle can be divided into two stages: Interphase (consisting of G1, S, and G2) and the Mitotic phase. Most cells spend a majority of their life in Gap 1 (G1) of Interphase, which is when the cell is performing the functions of its cell type (e.g., a cardiac muscle cell in G1 is helping operate the heart and a plant root cell in G1 is involved in water transport). Once a cell in G1 commits to dividing, it enters the Synthesis (S) phase, which is when DNA replicates exactly. Once the DNA is replicated, the cell can no longer perform as a “normal” cell; therefore, it enters the Gap 2 (G2) phase and continues to prepare for mitotic cell division. Once all steps are taken to prepare for division, the cell enters the mitotic (M) phase, consisting of mitosis (nuclear division) and cytokinesis (cytoplasmic division). The end result of the mitotic phase is two identical daughter cells, each of which contains an exact copy of the DNA. Historically, it was not known whether DNA replication occurred before the M phase during Interphase or during the M phase itself. Well-designed experiments showed that DNA replication happened during interphase and that there were gaps both before and after DNA replication. Students can model the steps of mitotic cell division in a three dimensional format (using building materials such as clay or pipe cleaners as above) and then create a movie out of the steps to show the continuous nature of mitosis. Students are not expected to memorize the steps of mitosis, but rather are expected to understand how the process works and allows cells to make exact copies of themselves. Models often help scientists visualize processes and concepts that are hard to “see”. After observing mitosis, students should be able to **explain** how the copies of DNA contained in the chromosomes is passed to the next generation through this process of cell division. Modeling mitosis and filming it helps students “see” the process. Extensions of this instructional segment can focus on what happens when there are mistakes in this process. For example, students can use the model to explain what would happen if the stages of mitotic cell division do not occur in order (i.e., if

cytokinesis occurs before mitosis) and they can have a discussion on cancer[3] and the effects of unchecked, out of control cell division on normal cell function.

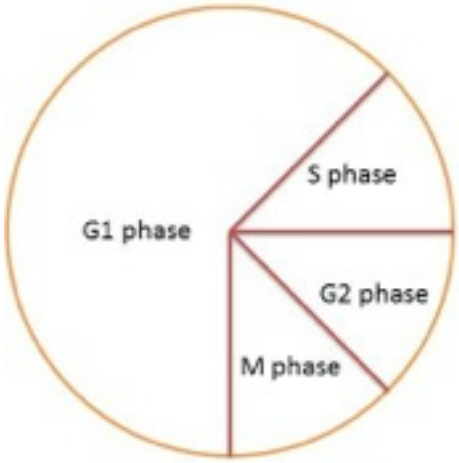


**Figure 7.** Stages of mitosis. The size of the pie is proportional to the time spent in each phase.

Further explanations of this instructional segment should include how cell division is the first part in the growth of a multi-celled organism and that as new cells are formed, they differentiate into specific cell types. These differentiated cells work together to form tissues, which then form organs that are often parts of a physiological system in multi-cellular organisms. Many multicellular organisms stop growing once they reach adulthood but mitosis does not stop. Some cells die off as they reach the end of their life cycle and these dead cells need to be replaced; this is done through mitosis of the remaining living cells. Extensions of this instructional segment might include discussions of stem cells that have not differentiated and have the ability to become a variety of types of cells leading to new tissue and organ formation. The future of stem cell use in organ transplant is one way that scientists are helping decrease rejection of

[3] Resources are available to look at cancer rates and types including http://www.cancerresearch.org/ which has short YouTube videos as well as the latest on cancer research. Make sure using reputable government supported research sites.

transplanted organs by the recipient of the donated organ. Stem cells can be used to generate signals for the recipient's body so that their immune system thinks that the organ belongs there. Other solutions to the problems of organ donation can also be introduced at this time by engaging students in researching the problem of matching suitable donors with patients. This provides an excellent opportunity to learn about the role of engineering in meeting critical medical needs. In addition to striking examples like MRI imaging and robotic surgery, engineers can even approach such problems as matching donors and patients by breaking down the problem into smaller, more manageable problems. Students can consider the different aspects of the problem of donor matching (awareness about the process by potential donors, rapid and reliable genetic testing, etc.) and brainstorm and evaluate possible solutions to them.

This unit culminates with students researching and **constructing an explanation** on the cascade effect of interdependent ***systems*** in the human body that occur in select diseases. One such disease is Amyotrophic Lateral Sclerosis (ALS, also known as Lou Gehrig's disease) . The cause of ALS disease is still uncertain and only 10% of individuals who have this mutation inherited it. Most of the time there is a random event that causes a neurodegenerative progression of the nerve cells in the brain and the spinal cord such that the muscles in the human body are not receiving messages and therefore begins to atrophy due to disuse. As the muscles atrophy, other ***systems*** in the body are affected. For example, muscles in the respiratory system stop working and the individual ALS patient has trouble breathing. Students' understanding of how human organ systems interact with one another can be illustrated using ALS as the example. Students should also research treatments and solutions that modern medicine has found for these diseases. Teachers' can highlight the importance of organ transplants for people whose organs start to fail due to disease and how donations of working organs and tissues from others can save lives.