Modeling the Coordination of Cell Structures

Sonic Hedgehog Protein Synthesis

After completing this activity, you should be able to describe the function(s) and spatial arrangement of each organelle within the cell and be able to describe the coordination among the organelles necessary for cellular function.

Background: Sonic Hedgehog protein (SHH) is an essential 462 amino acid protein produced in vertebrates during the early stages of embryonic development [1]. The protein is encoded by the shh gene, which in humans is located on chromosome 7 [2]. The SHH protein that is produced by this gene is called a "morphogen," or chemical agent that drives morphological changes in an organism. After synthesis, a cholesterol molecule is added to the C-terminal end of the amino acid sequence, and SHH is secreted by the cell into the extracellular space [3]. Once SHH is outside the cell, it forms a concentration gradient that promotes the development of several types of specialized tissue including the brain, spinal cord, and limbs and digits in vertebrates [4].

Scenario: Imagine that your classroom is an embryonic stem cell formed by the process of fertilization during sexual reproduction of two mice. During the first few days of development, you (the cell) receive a signal that it is time to begin the development of a spinal cord and limb tissue. Your task is to work together with your associated organelle partners to produce the SHH protein from the shh gene and export the final protein from the cell into the extracellular space.

Activity Instructions

Part 1: Strategize the Cellular Process

For each of the following steps, record your responses in table 1 and figure 1.

1. Discuss the functions of your specific organelle and what role your organelle will play in this scenario.

2. Talk with other groups to determine what other organelles or cell structures your group will interact with to complete the task in the scenario.

3. Construct a diagram of the sequence of events that must occur to complete the given task.

4. As a class, confirm with your instructor that the sequence of events is correct and modify your diagram with any changes. Do not go on to Step 5 until indicated by your instructor.

Part 2: Model the Production of SHH

5. Assuming the walls of the classroom are the boundaries of the cell, choose the appropriate location within the "cell" for your organelle and position yourself there.

6. Using the props, carry out the scenario from beginning to end. At each step the members of the organelle must act out the function of the organelle and explain the details of the process to the class.

Table 1. Structures and functions for “Sonic Hedgehog Protein Synthesis.”

Key Cell Structure	**Functions**
Nucleus/nuclear pore	
Ribosome	
Rough endoplasmic reticulum	
Cytoskeleton and motor proteins	
Golgi apparatus	
Smooth endoplasmic reticulum	
Plasma membrane	

Figure 1. Diagram the sequence of events to complete the production of SHH

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Questions

1. Assume that during the process of creating the SHH protein an error was made. Instead of producing a 462-amino-acid-long protein, you only make a 20-amino-acid-long protein. Assume the error is detected in the golgi apparatus. Will this protein be exported into the extracellular space? If your answer is no, what will happen to this protein?

2. What if the SHH you are making needs to be accumulated in the cell so that it can be released all at once into the extracellular space at a specific time? How would you store the produced SHH? What would need to occur to release all of the SHH from storage into the extracellular space?

3. Now assume that the protein you are making is one that is not destined to be secreted into the extracellular space, but instead is meant to function within the cytoplasm. How will synthesis of this type of protein be different? Why?

References

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