Cell Communication: The Passage of Ions Through a Cell Membrane.

Summer M. Sweet

Washington State University

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Abstract:

A model was created to present the properties of a cell membrane in a neuron and its properties in producing an action potential to fifth-grade students. My Neurophysiology class here at Washington State University assigned us to develop ideas to build a model, which could be presented at the Kids Judge with Brains Science Fair for elementary students to learn more about neuroscience.

The model constructed is about ion channels and the diffusion of ions across the cell membrane. Cell chambers, two cups and a lid with holes, and ions, whoppers and tiny tarts represented the passage of ions across the cell membrane. The students were asked to get in a line and conduct an action potential by depolarizing the cell chambers, tipping them over. Each model was judged by the students in individual surveys and a contest, our model received high individual marks and placed third out of the five

projects. Our model was a success the students judged it to be fun and a learning experience and they seemed to want to learn more about the subject.

Introduction:

A model was constructed for fifth-grade students at the Kids Judge With Brains Science Fair at Washington State University. The model introduced to the students was about ion channels and the cell membrane. Since this is a difficult subject to teach fifth-grade students we felt that it must be simplified. My partner, Vainio and I felt that some things needed to be left out, so that the students were not bored with the subject or not interesting enough. In this section the properties of an action potential across the cell membrane is discussed.

"Ion channels are usually based on the separation of the two main functions, permeation and gating" (Bezanilla, 1985). Permeability of the cell membrane is the ability of ions to passively diffuse across. These ions are moving with their concentration gradient to keep the cell at an equilibrated state, having no change in potential. It was found by Boyle and Conway and stated by Hodgkin that membranes are assumed to be mainly permeable to both potassium and chloride, but impermeable or sparingly permeable to other ions. For ions to move to create depolarization of the cell, they must be moving against their concentration gradient to create a potential difference in the cell membrane. The equilibrated state is at rest, meaning that the potassium ions are highly concentrated inside the cell and the sodium ions are highly concentrated outside of the cell membrane (Hodgkin, et al, 1959).

“The gating is assumed to be some type of blocking or unblocking and blocking of the pore to the passage of ions” (Bezanilla, 1985). These ion channels are influenced by e.m.f. causing the depolarization of cells, further causing an action potential. The concepts of gated channels were difficult to understand at a fifth-grade level, so it was appropriate to portray neurons as to passively diffusing ions across the membrane.

We considered using the students to resemble a myelinated axon because “ during the transmission of action potentials in a myelinated axon the sodium channels are confined at the nodes of Ranvier. (Bolis, et al, 1986) The students in line were used as different cells, instead of a myelinated axon, so they could understand that neurons must communicate in order to provide a reaction to a stimulus. We did not mention synaptic transmission because we felt it was a difficult subject for the fifth-grade students to understand. Using cell membranes and ions were elementary and could physically be constructed for the students to see and better understand the concept of neurons and their permeable membranes.

The cell chambers constructed were used to symbolize the inside and outside of a cell with its ions separated by a cell membrane, in which the sodium ions are freely moving across when tipped correctly. The model is best described below in the methods section.

Methods:

The model built by Lauren Vainio and I can be considered as cell chambers; five cell chambers were built. Each cell chamber was built with 2 plastic medium-sized cups and one lid. The cups were used to symbolize the intra and extracellular portions of the cell as the lid with holes in it represented the cellular membrane. The holes that were made within the lid were to represent protein channels; these holes were only big enough for the sodium to pass through, though. The potassium ions were brown whoppers and the sodium ions were colorful tiny tarts. The construction consisted of cutting the wholes in the lids and using a glue gun to glue one chamber filled with potassium ions to the top portion of the lid. The bottom portion of the lid was placed on top of the other chamber consisting of both sodium and potassium ions. These cell chambers were used by the students to see the passage of sodium ions from outside of the cell to the inside, creating an action potential.

The display on the table consisted of a board, used to observe pictorial representation of what an actual cell membrane looked like, and two enlarged cell chambers. The two cell chambers were constructed to accurately represent a cell at resting potential and its excited state. These were built with 4 one-liter soda bottles and Styrofoam, to represent the cell membrane. The ratio between sodium and potassium ions were accurately represented for the students to further understand the complexity of a cells intra and extra cellular concentration of ions.

The task the students were asked to perform was to represent the correlation of ions with cell communication. The groups of students were asked to form a line. Five of the seven participants each held a cell chamber and were asked when stimulated to tip the chamber upside down to represent an the depolarization of a cell, by allowing the sodium ions to pass the cell membrane into the cell. The first student without a cell chamber, where they were asked to be as creative as possible, caused the stimulation. Once the stimulation occurred each of the students with a cell chamber performed the action as stated above until the last student, without a cell chamber, received the stimulus and provided an action.

After each presentation, 37 students were asked to answer questions on a survey. They were then asked to rate each of the five teams on a scale from 1-5, from most liked to least liked.

Results:

After the ballots were turned in, our project placed third out of the five projects. This is an average ranking overall, though when the surveys were analyzed, our project received higher than average rankings. On the last three questions: fun, learn more, and overall average score, our project had the highest calculated averages. The average score for each of the questions were 4.81, 4.86, 4.86, 4.14 and 4.67 out of a 5-point scale. The main concern with the averaged results from the survey was to see its correlation with the ballots. In our case, the survey better represented the presentation as a whole. When the averages from the survey were compared to the other groups we saw that our presentation received some of the highest reviews, mainly concerning the overall averaged score. Though when you look at the ballots our presentation received third place. Refer to the Table 1.1.

The last two questions from the survey asked the students for their favorite part of the presentation and what they learned from the presentation overall. The most frequent response to the students' favorite part of the experiment was eating the candy, the sodium and potassium ions, and the next most common response was that they enjoyed shaking the cell chambers. There were a number of responses from the students about what they learned from the presentation. The most frequent response was that they learned there is a chain reaction between cells when excited. The other common statement was that they learned cells communicate with each other through networks. Others did not respond or they mentioned cells, cell membrane, and sodium and potassium ions. Overall it seemed as though the students received enough information to understand the topic of cell communication through the cell membrane.

Discussion:

The results show that the students understood most of what was presented to them. Not only did their feedback from the surveys show that they learned about cell communication, ion channels and ions but also they enjoyed the presentation as a whole. I believe that the interaction with the students and cell chambers really allowed them to learn and enjoy the topic being presented. The free candy that was there was very much liked by the students, which I believe was an added bonus to the project. The presentation itself seemed to be suitable for fifth grade students and enough information was presented to them at a level that is easily understood.

The simplicity of the model was inaccurate representations of the functions of what an ion channel does to depolarize the cell to further communicate with other cells. The students turned the cell chambers over to allow the influx of sodium ions into the cell through the ion channels. Some of the students believed that the neurons actually tip over to create the passive diffusion of sodium into the cell. What the students do not know is that there is a change in membrane potential caused by the potassium ions to open the sodium channels. "The potassium ions leave a cell through potassium selective channels become unbalanced positive charges on the outside of the cell, produces a potential across the membrane with the inside negative with respect to the outside" (Stewart, 1999). The ion channels did not represent the ions selective-channels; instead it was built to be large enough to get the sodium ions through and without allowing the potassium ions to move freely across the membrane.

The two displays of the cells at rest and at excitement represented the intracellular and extracellular ions' concentrations accurately to make up for the inaccurate ratio of ions in the cell chambers. The whoppers and tiny tarts accurately represent the potassium and sodium ions when considering size, though the ion channels are different in size. The sodium ion channels are larger than the potassium ion channels due to the amount of water molecules attached to the sodium ions.

Using electrical and mechanical engineering could improve the cell chambers. The cell chambers would not have to be tipped but instead a trigger button could be pushed to the ion channels to selectively allow ions to pass. A device that can act as sodium-potassium pump could be developed to give an accurate representation of how the cell activates depolarization in the cell. Though this idea is more accurate, I don't believe it would be more fun for the students to push a button and watch, its' not as interactive as our constructed model.

The simplicity of the model gave the students a generalized sense of what causes depolarization of a nerve cell- neuron. The influx of sodium ions were our main concern because we wanted the students to understand action potentials and that it is a precursor to any communication between neurons. Considering the complexity of ion channels and the passage of ions through them, it was difficult to construct a basic model that fifth grade students with little prior knowledge of neuroscience would understand.

Tables

		Q1 Understand	Q2 Friendly	Q3 Fun	Q4 Learn More	Overall Average	Place Vote
Don't Stick That In Your Ear	B1	4.81	4.87	4.60	4.08	4.59	First
Edible Excitable Neuron	B3	4.50	4.59	4.67	3.92	4.42	Second
Sweet Potential	B2	4.81	4.86	4.86	4.14	4.67	Third
Nerve Channel Basketball	B5	4.32	4.76	4.68	4.03	4.45	Fourth
Human Salt Bridge	B4	4.30	4.70	4.40	3.70	4.28	Fifth
		-0.75	-0.23	-0.37	-0.60	-0.62	Correlation

Table 1.1. Averaged scores from the five-question survey amongst the groups as well as their place vote. The correlation represents the slope of the line from a plotted graph.

References

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