Bonnie Larson
Neuro 430
Kids Judge Neuroscience Fair 2006 Exhibit
(with: Andrew Ensslen, Amanda Foust and Erin Zimmerman)
Writing in the Major Assignment

Putt Putt Pathways

Abstract

The Kids Judge! Neuroscience Fair tries to introduce complex neuroscience concepts to fifth graders so they are able to comprehend the basic ideas and have fun by reinforcing the idea through an activity. The kids then judge the different models based on how well they understood the concept, the friendliness of the presenters, how fun they thought the game was and how interested they would be in learning about the concept in the future. Our model focused on ion channels which are important for ion movement through the cell membrane. When cell signaling occurs, the channels open rapidly and the ions move quickly through the channel to change the membrane potential, causing the signaling cascade to continue. If the cell is not being signaled, ions are still able to move through the channels, but do so more sporadically. We demonstrated ion movement when the cell is at rest through our activity, Putt Putt Pathways. The kids putted "ions" through a channel that was specific for either potassium or sodium. The kids really liked the game and seemed excited about our concept by the end of the presentation. However, based on their judging results, they had the most difficulty understanding our concept in comparison to the three other groups in our judging category. This may have been because of the complexity of the concept or because of how we initially presented the material.

Introduction

Ion channels play an important functional role in producing action potentials. In order for an action potential to occur, channels of some sort must be activated. Variations of these channels include second messenger channels, ligand- binding channels, and voltage-gated ion channels. The cell's membrane potential must change during an action potential. One of the most common ways this change occurs is through the movement of ions through the channels.

Understanding how these channels function and are selective is beneficial to research that focuses on drug binding, activation and inactivation caused by drugs, and the effects caused when channels do not function correctly for various reasons such as drug use or mutation. Improper function of the channel to activate or inactivate appropriately could cause unwanted changes within the body.

Both sodium and potassium channels are important to the action potential. Na+ channels become quickly activated and then inactivated during an action potential. Hodgkin and Huxley discovered that these sodium channels reach complete inactivation after a large depolarizing action potential. (Ulbrict 2005) Inactivation of the Na+ channels can be fast or slow. When the sodium channels are open, the membrane potential becomes more positive. As it reaches sodium equilibrium, around 55mV, the sodium channels become inactivated and the K+ channels open. Potassium can now reenter the cell and the membrane potential will become more negative, returning to the resting membrane potential (Yellen 2002). Potassium channels change conformation to allow potassium to pass when they sense a voltage change (Tombola 2005)

In order for an action potential to occur in the presence of voltage-gated ion channels, Na+ channels must first open, followed by K+ channels. Because both of these ions are positive and similar in size, how do the ion channels select for the individual ions? Sodium is the smaller of the two ions, so if the sodium channel was selective for size, it would not allow potassium to pass through. However, in this scenario, sodium would be able to pass through the potassium channel. How then are the channels so specific that they are able to allow only a specific ion through and cause depolarization and repolarization of the membrane? First, both ions are surrounded by water. Because K+ is the larger ion of the same charge, it does not bind water molecules as tightly as Na+. As it begins to move through the channel, it is stabilized by water present in the channel. It is also stabilized by the negative end of a helix dipole. The K+ is thought to be surrounded by oxygen molecules while it is in the channel. Finally, multiple K+ ions move through the channel in a single file causing the repulsion of the other K+ ions with enough strength to continue to move the ions through the channel. (Yellen 2002)

Sodium channels, too, must have a selectivity filter. Sodium ions are also surrounded by water, but bind it much tighter than potassium ions. The pore contains a negative binding site that allows sodium to bind and temporarily detach its water molecules. Once past this site, water binds to the ion and allows it to stabilize again. It is thought that, although the Na+ channel is bigger, K+ ions cannot pass through it because the positive charge on K+ ions is not strong enough to be stabilized in the channel by the negative binding site. (Ulbricht 2005, Kandel et al. 2000)

Ion channel selectivity allows ions to pass through their respective channels and allows cells to depolarize. Without a control of ion movement, action potentials would occur spontaneously, if at all. Action potentials are necessary to carry out functions of the body and respond to internal and external environmental changes.

Our project will show students that ion channels are selective for their respective ions. We will begin with a presentation on the brain and the cells within it, followed by a discussion on cell membranes when we will introduce the concept of ion channels as part of these membranes. Next we will show students a periodic table to help them understand the concept of an ion and teach them that ions move through the channels to help cells send signals through the body. To enhance this learning experience, students will play putt-putt pathways, a derivative of putt-putt golf, and have to get golf balls, representing ions, into the designated channel. Because of the difficulty in demonstrating exactly how the channels are selective, we will use two colors of golf balls and each color will only be allowed to go through its respective channel. We will close our activity by having the kids shout “channel” when we say “ion”, reinforcing the basic idea and giving them a way to remember what they learned.

Methods

We designed our experiment to correctly and simply explain the idea of ion channels to the fifth graders. First we built part of the cell membrane by placing two pieces of foam about eight inches apart and secured them by adding a stabilizing piece of board to each end to help it stand up. Next, we cut two semicircles, representing channels, out of the bottom portion of the cell membrane. We lined these semicircles with eight long balloons, which were blown up to about ten inches but still had about eight inches of non-blown up space. Each semicircle had a pattern of colors similar to the color of golf balls that were going to correspond to that channel. The balloons were taped into the semicircles with the part that was not blown up going one direction for one circle and the other direction for the other circle. The balloon "tails" helped to keep the golf balls from going through the wrong channel. We labeled one channel as sodium and the other as potassium. The kids that were trying to hit the sodium ions through the channel were said to be inside the cell and the kids hitting the potassium were outside of the cell. The ions were colored golf balls: sodium was silver and potassium was red. We used to cardboard golf putters and measured a distance of four feet from each hole, so the kids were standing an equal distance away on each side.

When the kids arrived at our station, we talked to them about the brain and cells within it, the cell membrane and then the channels that were part of the membrane. Next we showed them the periodic table and talked about ions and how they made up certain things such as salt, NaCl, and were highly concentrated in foods such as potassium sticks, or bananas. We introduced the game to them by showing our small fraction of the cell membrane with two ion channels in it. At this point, we discussed selectivity by telling them that ions can only go through their own channels and potassium goes into the cell while sodium leaves the cell. The kids formed two teams and had to race to get twelve ions through the correct ion channel. Each team lined up on the respective side of the membrane according to which ion they were trying to move through the channel. They took turns trying to hit an ion through the channel. If it did not go through or went past the side of the membrane, it did not count and that ion had to be hit again.

Results

Our model was received well by the kids based on our first place in the group that we were competing in during the judging. The other people in the "G group" had interesting and exciting projects also. During the period when the kids were judging the projects, the kids seemed to enjoy themselves and what we were teaching them. They laughed at the phrase "potassium stick" and liked the idea of calling salt, NaCl.

Based on the ratings of the kids from the G groups, our project ranked first in the fun category, but third in the category asking if they understood what we were trying to teach them. They seemed to understand the basic concepts at the beginning of our presentation and easily understood the game. Most kids wrote comments about the fun game but a few did mention that ion channels had to have specific ions go through them. At the end of the project, we shouted "Ion" "Channel" to reinforce the basic terms; this seemed to help kids remember the most basic idea.

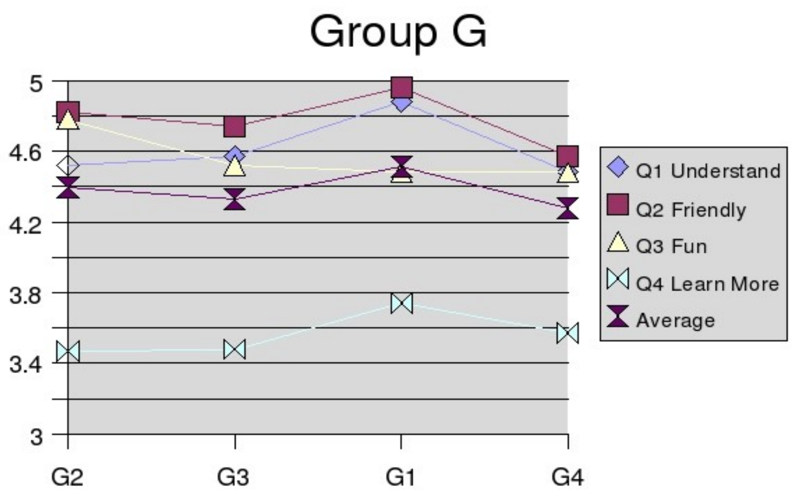

Figure 1. Our project, Putt Putt Pathways, was group 2. This chart shows how the kids graded our project. It compares the four projects in group G. The groups are listed in the order they were ranked when judged.

Discussion

The Kids Judge! Science Fair was an excellent way to get kids excited about the field of neuroscience. Many concepts that neuroscientists explore are abstract and difficult to understand, so trying to present these concepts to fifth graders was quite a challenge. We did not want to provide them with inaccurate information but we wanted them to understand the basic concepts studied in neuroscience and why they were important. Our project successfully taught kids that science can be fun, and gave them a very basic idea about why channels are important. However, our project was a very simplified version of what happens with ion channels. Limitations in what we could present and what they would understand included the movement of ions through the channels, how channels open and close, and other ions involved in the movement across the channels. We said that potassium wants to move into the cell while sodium wants to move out of the cell. This is true until an action potential occurs and the cell moves closer to sodium potential. As it gets closer to this value, the direction of ion movement will reverse. We were not able to show channel opening or closing or the other types of channels and ions present within the intra- and extracellular fluid.

Conclusion

Although our project took first place, it was ranked the lowest for how well the kids understood the concept (Figure 1). This is slightly disappointing because ion channels are a large part of neuroscience; however, if one of the other topics interested them enough to possibly want to study neuroscience in the future, then the fair was highly successful. In order to improve our project, we should have prepared a dialogue that consisted of wording that the kids would easily be able to understand. We had a basic outline prepared, but did not rehearse exactly what we were going to say. If we had decided which group member was going to discuss which topic, the ideas that we presented would have flowed much better, helping us to better convey the concepts to the kids. We should have also reinforced the idea that while the kids were playing the game, they were not demonstrating what was happening at the ion channels when a signal was being sent, but instead while the cell was at rest. During the discussion, we mentioned that ions were an integral part of cell signaling, however, I think that the kids may have misinterpreted the game to represent what happens during signaling. Our model depicted ion movement through the channels when the cell membrane potential is at rest. The model, with the balloon tails blocking most ions from going through the wrong channel, nicely demonstrated that ions can only go through their specified channel. However, another idea the kids may have gotten from this was that the ions only move in one direction. To introduce more concepts than ion channel specificity, and therefore adding more details to the model, would have been very difficult in the time we were allotted and would have made it more difficult for the kids to understand. Our project had many limitations but presented the basic idea to kids in a way that they some what understood and enjoyed, the purpose of the fair.

Works Referenced

Devor, M. Sodium Channels and Mechanisms of Neuropathic Pain. The Journal of Pain (2006) 7, S3-S12.

Kandel, E., Schwartz, J., Jessell, T. Principles of Neural Science. McGraw-Hill (2000).

Tombola, F., Pathak, M., Isacoff, E. How Far Will You Go To Sense Voltage? Neuron (2005) 48, 719-725.

Ulbricth, W. Sodium Channel Inactivation: Molecular Determinants and Modulation. Physiological Reviews (2005) 85, 1271-1301.

Yellen, G. The voltage-gated potassium channels and their relatives. Nature (2002) 419, 35-42.