

**NERVE CHANNEL BASKETBALL: A MODEL OF THE STRUCTURE AND  
FUNCTION OF A LIGAND-GATED ION CHANNEL**

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**APRIL 29, 2003**

**ABSTRACT**

The purpose of our modeling project was to visually demonstrate the structure and function of a ligand-gated ion channel to a group of fifth grade students. Ion channels are central to the excitability of cells, particularly in the nervous system, because they allow for the selective movement of ions in and out of the cell at near diffusion rates. We constructed our model using a trash can that served as the channel pore, Styrofoam filled bags, which served as channel proteins, tennis balls for ions and a cell membrane made from poster board. During the presentation, one presenter acting as the ligand binding site, opened the trash can lid and the kids each tried to throw a tennis ball (ion) through the ion channel. The model was well received by the students who seemed to understand the basic concept we were trying to convey. The kids, who were given the opportunity to vote on the different presentations, placed our model in fourth place out of the five presentations in our group. We were encouraged by their comments and questions and believe that our objectives were met successfully.

## **INTRODUCTION**

The idea of the ion channel was first proposed by Bertil Hille who described ion channels as macromolecular pores in cell membranes (Hille, 1984). Cell membranes are impermeable to most molecules and there needs to be a way in which the cell can selectively move ions in and out of the cell to facilitate action potentials. It was previously proposed that perhaps the mechanism through which ions were transported in neurons was through carrier-mediated transporters (Miller, 1986). However, the speed with which ions were moving during action potentials was found to be three orders of magnitude faster than could be mediated by transporters (Miller, 1986). The passage of ions through ion channels has been recorded at near-diffusion rates of 100 million ions per second through a single channel (Capener et al, 2002).

Although discovery of the ion channel was fundamental, it led to even greater questions about the structure of these channels and their functional mechanisms. To date, many of these questions have been answered, but much is still unknown about ion channels. Various techniques were used to discern the structure of ion channels. With the advent of DNA and amino acid sequencing, the protein nature of the channels could be described. Through X-ray crystallography, it was possible to determine the specific structural arrangement of amino acid residues in the channel proteins and in doing so provided insight into the complex functioning of the channels (Miller, 1986).

Generally, ion channels are known to be made up of protein subunits that are embedded in the cell membrane. The cell membrane is a phospholipid bilayer and as such

is hydrophobic. For this reason, it is seen that amino acid residues in the ion channel that traverse the cell membrane are mainly hydrophobic. Similarly, the parts of the ion channel exposed to an aqueous environment are found to be composed of primarily hydrophilic amino acids (Latorre, 1986).

There is a pore in the centre of the channel that regulates the passage of ions in and out of the cell. Most ion channels are selective for specific species of ions; they may be selective for different ions with a certain charge, or even for a single type of ion such as sodium. This selectivity arises from the placement of strategic amino acid residues within the ion channel pore (Latorre, 1986). Since amino acids vary in size and charge, the size of amino acids comprising the pore limits the size of ions that can pass through the pore and charged amino acids will attract ions of like charge and repel ions of the same charge .

Ion channels can be classified by the mechanism of gating which refers to the process of opening and closing the pore. The process of opening and closing ion channels occurs through changes in conformation of the proteins comprising the pore. Certain conditions, which vary between channels, favor the opening and closing of ion channels. The three most common mechanisms of gating are voltage-dependent gating, ligand-dependent gating and mechanical gating. Voltage-gated channels are open over a specific range of transmembrane voltage, ligand-gated channels are opened by the binding of a small molecule such as a neurotransmitter (Miller, 1986) while mechanically gated channels require the physical displacement of the lipid membrane that is in contact with the ion channel.

The purpose of our model was to illustrate the known structure and functioning of ligand-gated channels. We set out to build a three dimensional model that visually depicted an ion channel embedded in a cell membrane. Since the audience was a group of fifth grade students, we endeavored to make the model fun and interactive by turning the ion channel model into a game of basketball.

## **METHODS**

### Materials:

Two chairs, poster board, eight tennis balls, trash can, ball labeled 'neurotransmitter', Styrofoam peanuts, large plastic bags, duct tape, coloring pens, scissors, small bin, short plastic pole.

### Procedure:

We began construction of the ion channel model by halfway filling five large plastics bags with Styrofoam peanuts and taping them shut to form five turgid cuboid structures. These then formed the five protein subunits in the ion channel. Next, we took a mechanical (lever-operated) trash can, whose bottom had been removed and taped the five protein subunits to the sides of the trash can. The trash can, now in the centre of the five protein subunits, was to serve as the pore of the ion channel. A short plastic pole was attached to the lever on the trash can and used to depress the lever that opened the lid of the trash can. Opening the lid to the trash can signified the opening of the ion channel pore.

On two pieces of white poster board we drew the image of a phospholipid bilayer using colored pens. We attached these two pieces of poster board to the ion channel structure, by taping one board to each side. We now had a cell membrane on either side of the ion channel. The entire setup, as illustrated in figure 1, was then suspended between two chairs, to ensure that ions (balls) would pass easily through the channel. We placed the small bin below the ion channel, in between the two chairs, to act as a receptacle for the inward flowing ions. This served as an oversimplification of the cell.

During the presentation of the model, a short explanation was given about the model and the function of the ion channel. Next, we gave each student a tennis ball to serve as an ion. One of the presenters acted as the binding site for the neurotransmitter and was to depress the lever and open the channel when the neurotransmitter ball was passed to them. Once the ion channel was open, the kids would attempt to throw their ball through the ion channel and into the receptacle (cell). Some of the balls would go into the cell, but others would bounce off, signifying that in reality not all ions pass through the ion channel. Occasionally, the lid would be shut signifying that the channel is not always open.

## **RESULTS**

The kids seemed to have a lot of fun with the presentation. They got carried away trying to get more balls (ions) to throw. Some of them asked very good questions about the model, concerning the size of the ion channel relative to the whole cell, the opening and closing of the channel and initiation of action potentials. Generally, they seemed to

understand the functioning of the model and what we had to say concerning ion channels. We placed fourth overall out of the 5 groups that were presenting in group B. This rank came as a bit of a surprise because I often heard the kids exclaim as to how much fun they were having. I did however hear two of the students say that they were going to vote for the groups that gave them candy and unfortunately, our group wasn't one of those.

Based on individual evaluations from the students, I think our presentation was very well received. The students were asked to fill out evaluation forms at the end of every presentation. The first part of the evaluation had four questions, each requiring a score of 1-5, in which 5 was the best possible score. These questions ranked the presentation on various aspects, such as whether it was understood, how friendly the presenters were, how much fun the presentation was and whether the kids would like to learn more about this topic. Our presentation received a score above 4 for every one of the categories. The highest scores were in the fun category (4.68) and the presenter friendliness category (4.76). The average score across all four categories was 4.45; this was third the best score in group B of presenters and did not match the voting ranking which placed us in 4<sup>th</sup> place. The category about how well the students understood the model had a score of 4.32 and of the four categories, this was the only evaluation ranking that matched the voting ranking.

On the evaluation form, there were also questions that required written responses from the kids about what they had learnt from the presentation and their favorite part of the presentation. Most of the students commented that they learned about ion channels, and that ion channels need to be open for ions to pass through them. Their favorite part of

the presentation was almost unanimously, getting to play basketball. There was a great wealth of comments which suggests that they understood the basic concept of the model.

## **DISCUSSION**

The modeling project was in many ways a success. We were able to build a model that visually demonstrated the structure and functioning of a ligand-gated ion channel. We also successfully presented the model to a group of fifth grade students in a manner in which they could understand and enjoy. The results of the student evaluations were very encouraging. They mostly commented that the presentation was fun and in their opinion, “cool”. We did have a few minor incidents of some overzealous students who attempted to throw the balls from a great distance, often causing some damage to the model.

To make our model and presentation better, I think we should have incorporated a reward system for the kids to encourage their participation in the model, such as the candy offered by other groups. Based on the evaluation results, I also believe that our explanation of the model structure and cell membrane was a bit complex for some of the students and a more simplified explanation if at all possible would have helped. To demonstrate the selectivity of the ion channels, we could have included balls of a larger size that would not fit through the channel, this way, only ions of a particular size would be seen to enter the cell.

The model itself was relatively simplified for ease of construction. This simplification however, meant that many details of the ion channel structure and

surrounding components were excluded. Extracellular and intracellular components of the cell for example were not shown. We did not demonstrate that each ion, as it passes through the ion channel, is surrounded by water molecules. The actual location of the gate was also not accurately demonstrated in our model; in a living cell, the gate is located deeper within the ion channel pore and is opened by changes in conformation of the pore and not through a hinged-lid mechanism as depicted by our model. However, I do not believe that any of these omissions in anyway reduced the effectiveness of the model in our presentation.

Overall, the modeling project was an invaluable experience in demonstrating neuroscience concepts, particularly to audience that is not expert in such subject matter.

## **REFERENCES**

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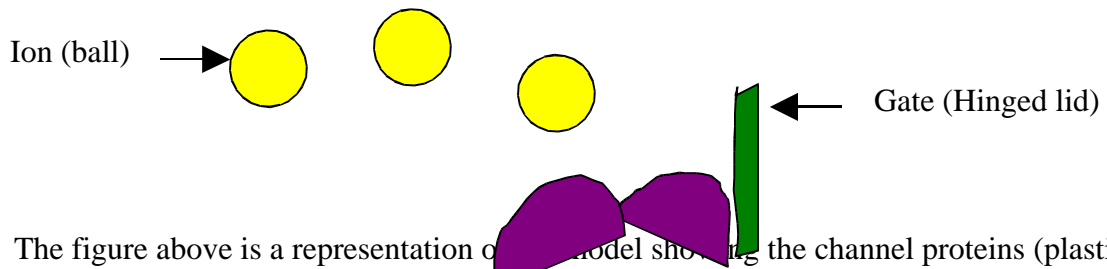
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**FIGURE**

Figure 1.



The figure above is a representation of a model showing the channel proteins (plastic bags filled with Styrofoam), the phospholipids (drawn on poster board), the Gate (the hinged lid on the trash can), and Ions in form of tennis balls.

Phospholipids

