BIO 131 PAL
Week 4 – Problem Set 2

Bad Fish: Human Anatomy and Physiology Edition

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Text and questions were extensively modified and questions were added by **Larissa Eiselein** to fit **BIO 131A** course content.

Part I – Poisoned!

One evening during a recent trip to Indonesia, Dr. Marshall Westwood from the Montana Technical Institute sat down to a meal of puffer fish and rice. Within an hour of returning to his hotel room, Dr. Westwood felt numbness in his lips and tongue, which quickly spread to his face and neck. Before he could call the front desk, he began to feel pains in his stomach and throat, which produced feelings of nausea and eventually severe vomiting.

Fearing that he had eaten some "bad fish" for dinner, Dr. Westwood called a local hospital to describe his condition.

The numbness in his lips and face made it almost impossible for him to communicate, but the hospital staff managed to at least understand the address he gave them and they sent an ambulance in response.

As Dr. Westwood was rushed to the hospital, his breathing became increasingly difficult.

Doctor's Notes:

The patient presented in the ED with severe headache, motor dysfunction, nausea, and an ascending paralysis that spread to the upper body, arms, face, and head. The patient was cyanotic and was hypoventilating. Within 30 minutes of presenting in the ED, Dr. Westwood developed bradycardia with a BP of 90/50. Atropine was administered in response to the bradycardia. IV hydration, gastric lavage, and activated charcoal followed a presumptive diagnosis of tetrodotoxin poisoning based on the clinical presentation in the ED.

Five hours after intervention, the following vitals were noted:

• BP 125/79

• HR 78bpm

• Oxygen saturation: 97% on room air

Follow-up

Within a few hours, Dr. Westwood's condition improved and he was on his way to a full recovery. After discussing his case with his physician, he learned that he had probably been the victim of a puffer fish poisoning. The active toxin in the tissues of this fish is a chemical called tetrodotoxin. Tetrodotoxin is in a class of chemicals known as neurotoxins due to the fact that it has its effects on nerve cells (neurons). Specifically, tetrodotoxin blocks voltage-gated sodium ion channels on neurons.

Questions:

1. As mentioned in the case description, tetrodotoxin is a molecule that blocks voltage-gated sodium ion channels. Why do sodium ions need channels in order to move into and out of cells? Describe the process involved in the movement of ions through these channels.

2. When nerve cells are at rest, there is an unequal amount of positive and negative charges on either side of a nerve cell membrane. This charge difference is called an electrical potential. Describe this "potential" when the neuron is at rest (resting membrane potential).

3. What is happening to the electrical potential of a neuron when it generates an action potential? Which ions are moving during each phase of the action potential?

4. What would happen to a neuron if it were exposed to tetrodotoxin? Be specific regarding its effect on the ability of a neuron to communicate.

5. Now that you have addressed some of the basic biology of this case, explain why Dr. Westwood experienced numbness, paralysis and hypoventilation after eating the puffer fish meal. You must explain all three symptoms individually.

BONUS:

6. Briefly describe the role of the autonomic nervous system in human physiology. What are the two divisions of this system?

7. Atropine was administered in the ED as part of Dr. Westwood's care. What effect did it have on his vitals after it was administered? Which part of the autonomic nervous system do you speculate does atropine block most effectively, given the improvement of Dr. Westwood's vitals?

Part II – Oh No! Not Again

After recovering from his TTX poisoning, Dr. Marshall Westwood decided to take a vacation. An avid birder, he decided to go to Papua New Guinea with Bill Whitlatch, an ornithologist friend of his from Montana Technical Institute.

Three days into their trip, Bill netted bird with an orange body and black wings and head for closer study. Dr Westwood was very curious and asked Bill if he could have a closer look at the bird. After handling the bird and then later wiping his mouth with his hand, Dr. Westwood noticed that his fingers and lips were going numb. His mind immediately flashed back to the disastrous trip to Indonesia and he began to panic. Luckily, the symptoms faded before they progressed into anything more serious.

His friend Bill used a key to identify the bird as a pitohui. The pitohui are small, social songbirds that live in Papua New Guinea. They are generally about 23 centimeters long with strong legs and a powerful beak. Their encounter was the first time anyone had scientifically realized the birds' toxicity.

Before releasing the bird, Dr. Westwood collected feather and tissue samples to bring back to the lab. After returning to Montana, he set out to isolate the toxic compound that he believed was being produced by the pitohui. It appeared that the active ingredient was a homobatrachotoxin, known to act on V-gated Na+ channels.

You and your colleagues received a call from Dr. Westwood asking if you could help elucidate the exact mechanism of action of this toxic compound.

Questions

1. In your first experiment, you generated action potentials in axons of large neurons obtained from squid in the presence of this new toxin. You found that after depolarizing, the membrane potential remained positive for an extended length of time, and the repolarization was often extremely delayed. Draw a graph (membrane potential in mV vs. time) to illustrate this effect (normal vs. with toxin).

2. As you continued to experiment with higher concentrations of the toxin, you found cases when the cell could not repolarize at all, or if it began to repolarize, it would immediately depolarize again. Speculate about the exact action of this toxin on voltage-gated sodium ion channels.

3. Honobatrachotoxin is an extremely potent poison. The lethal dose for a 68 kg (150 pound) person tuned out to be approximately 100 micrograms, or equivalent to the weight of two grains of ordinary (fine) table salt (NaCl). Knowing the mechanism of action for this poison, explain what will cause death, if exposed to it.