



The Tired Swimmer: A Case Study on the Nervous System

by

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Part I—Meet Annie

Annie felt despondent. Her team mates were being kind to her, but she knew that she was the reason that her team lost the swim meet against the neighboring college. How many people could lose with a four-second lead on the anchor leg of a 50-yard relay against someone they had beaten so easily last year? As she walked out of the locker room she noticed that the blurred vision and eye strain had returned, even though she was wearing glasses instead of her usual contacts. Maybe no one will recognize me with these on, she thought. Annie hated wearing glasses. Her eye strain had become worse over the past month. Over the last week she had had mid-term exams and papers to write and recently typing made her hands and fingers ache and they felt weak. Even swim practice, which helped relieve her stress in the past, had become taxing. Her coach noticed that her times were getting worse, even though he could see that she was working hard in practice.

As Annie walked out of the locker room she looked up and she saw her boyfriend, Matt, waiting for her. He attended another college and had made a detour to drive her home for mid-term break.

“Thanks for driving all this way to take me home, Matt. I’m sorry that you made it early enough for the meet; I was really bad. I just don’t know what’s wrong with me these days.”

Matt didn’t know what to say, so he smiled and took her hand. As they walked back to her dorm, Annie thought how nice it was to have Matt to support her during such a tough time. Annie was gasping for air and felt weaker than ever after they had walked up the two flights of stairs to her floor. She told herself that she must set some time aside next week to do something about this constant fatigue.

Annie had already packed her bags for the trip home and Matt was able to carry all of her stuff to his car in one trip. When he returned to the room he found Annie lying on the bed with her eyes closed. He asked her if she was ready to go.

“Sure, just can’t keep my eyes open these days. I am sure I’ll be better when we’re home.”

Matt knew that Annie liked to drive, so when they got to the car he handed her the keys. She tried to take them, but her fingers didn’t seem to work and she dropped his keys on the ground. Matt grabbed the keys and opened the passenger door for Annie. As they set off for home, Matt asked, “Are you feeling okay? You’re not usually so exhausted after a swim meet, and you seem to be having trouble catching your breath. I am worried about you.”

“I have been feeling really tired over the past month or so, and I guess mid-terms took more out of me than usual.”

“Why don’t you take a nap for the next couple of hours; I’ll wake you when we’re home.” Matt thought that this was probably not the best time to suggest that she see a doctor.

Questions

1) What vital signs or symptoms does Annie Exhibit?

- despondent
- Blurred vision
- Eye strain
- Hands and fingers ache and feel weak (cannot hold on to keys)
- Swimming performance is getting worse
- Gasping for air
- Feeling weak
- Sleepy
- Fatigued
- Tired

2) Can you see any common features in Annie’s signs and symptoms?

- Many involve muscle weakness

3) Why is Annie having problems breathing?

- Weak breathing muscles — diaphragm and intercostals muscles

4) What are the possible reasons for Annie’s condition?

- muscle weakness

Part II—The Doctor's Office



On Monday afternoon, Matt drove Annie to her family doctor. She seemed to have slept for most of the weekend, and Matt thought that she looked much better than last Friday after the meet. In fact, she told him that she felt so much better that she really didn't need to go to the doctor.

"Seriously, this is stupid. I've been feeling much better in the past few days. It's amazing what some rest can do. That's all I need; I really don't need a doctor as long as I take a nap every once in a while. Let's not waste his time; let's just go home."

Matt looked at her with his eyebrows raised, "Let's just hear what he has to say; better safe than sorry."

Matt sat in the waiting room and Annie went with the nurse. After a few minutes Dr. Jones entered the cubicle, "Well, Annie, what seems to be the problem?"

"It's nothing, really. I have just been tired lately. You know I'm going to college on a swimming scholarship, but my times have been getting worse this season, and I've been short of breath more than usual after my workouts. I think it's just because I was stressed out over school; I have been feeling much better since I came home last Friday."

"I see," said the doctor. "Have you had any other problems?"

"Well, yes. My hands and fingers seem to get tired when I type, and a few days ago, after a swim meet, my fingers felt too weak to grab my boyfriend's car keys when he offered them to me; but I was tired after a really hectic week."

Dr. Jones looked pensive and asked, "Have you had any trouble with your eyes?"

Annie looked confused. "I have had a lot of eye strain and double vision recently. It gets blurry when I stare at the computer screen too long; I seem to get a zillion papers every week. I also think the chlorine level in the pool is too high. Everyone on the team complains about it because, if your goggles come off, your eyes sting like mad. I even had an attack of the drooping eyelids the night before the swim meet, but I was really tired then."

The doctor smiled, "I swam before those goggles were even invented, so I know what you mean about stinging eyes. But, I think what you're telling me goes beyond simple fatigue. I'm going to refer you to a neurologist at the hospital."

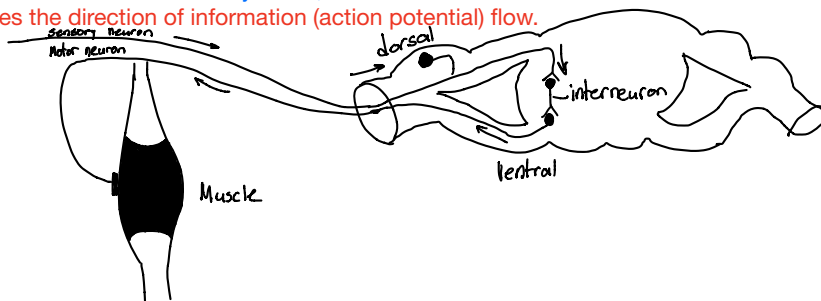
Questions

1) What additional vital signs or symptoms does Annie exhibit?

- Stress
- Double vision
- Stinging eyes
- Drooping eyelid

2) Draw a cross section of the mammalian spinal cord, including the dorsal and ventral roots and draw a muscle to one side of the spinal cord. Draw in a reflex that includes a sensory nerve, an interneuron and a motor nerve.

- Arrow denotes the direction of information (action potential) flow.



3) How could a decline in muscle function contribute to eye strain and blurred vision?

- Muscles move the eyes so that you can focus on an object. If a muscle movement is insufficient, the muscles must contract again in order to make a correction, and these additional contractions cause the muscles to become "strained". Also, since these additional contractions take time, the eyes are not always focused on the object and result in a blurry image.

4) What are the possible reasons for Annie's condition?

- Clearly a muscle problem

Part III—The Neurologist



Annie returned to the neurologist's office with her mother. That morning Annie had been subjected to several different tests and she had been asked to return after lunch when the results would be in. The nurse told her that they were rushing this through because they knew that Annie was only home for a week. Annie and her mother sat in the waiting room for what seemed to be hours. At last the nurse came for them.

"Some of the results are here, and the rest are on their way," she explained. "So the doctor will see you now." Annie and her mother went into the doctor's office and sat down.

"Well, Annie, I have read your family doctor's notes, and we put you through a battery of tests this morning."

The neurologist skimmed through the chart, "Hmm, blurred vision, weak fingers, and decline in swimming performance. OK, let's see what we found out today. First, the nerve conduction and the electromyography (EMG) tests; these are the only results we have right now. This was the test when they put sticky electrodes on your skin, remember?"

Annie nodded.

"Well, for the nerve conduction tests one set of electrodes stimulated the nerve and another recorded its response a little way down the nerve. The nerve conduction results are normal. There is no nerve fatigue and the conduction velocity is fine; nothing wrong with your nerves."

Annie and her mother looked at each other and smiled with relief.

"Now, the electromyography test involves recording from a muscle; it was done in two stages. The first stimulated the muscle directly, and there isn't too much out of the ordinary there. The second stage is when the nerves were stimulated and the muscle response was recorded. These results concern me because the muscle response decreased quickly during repeated nerve stimulation, indicating that your muscle response fatigued over time."

Questions

1) According to the conduction test, was Annie's nerve function normal?

- Yes

2) According to Annie's EMG test, was Annie's skeletal muscle function normal?

- Yes

3) Considering your answers to questions 1 and 2, why did activity in Annie's motor nerves produce a skeletal muscle response that fatigued during repetitive stimulation?

- synaptic function is compromised

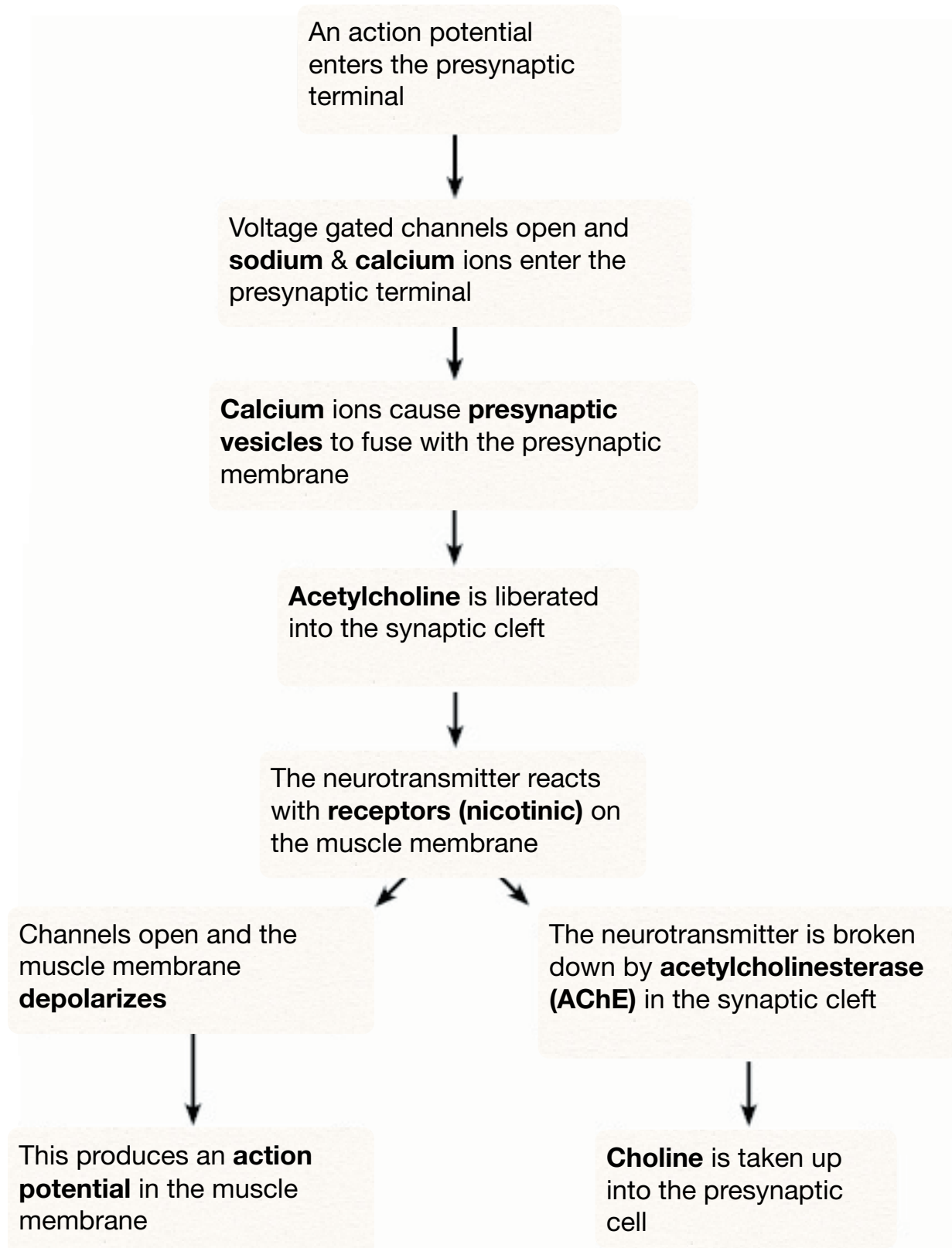
4) Fill in the blanks in the accompanying flow chart of the neuromuscular junction

- See next page

5) now take each stage in turn and discuss how sustained neural activity could create a dis function and result in a decrease in muscle response during repetitive motor nerve stimulation:

- Sodium and calcium channels stay closed during repetitive nerve activity
- Less calcium enters the presynaptic terminal during repetitive nerve activity
- The number of vesicles declines during repetitive nerve activity and they are not replenished
- Vesicles are smaller, and have less acetylcholine
- Fewer receptors on the muscle membrane to react with acetylcholine

The Neuromuscular Junction



Part IV—The Neurologist Continued



They heard a knock at the door and turned to see the nurse enter; she was holding a folder with the hospital's stamp.

"Ah, the lab results," exclaimed the doctor.

The neurologist turned the pages with a frown. Annie took her mother's hand as they looked at one another.

"I'm afraid I don't have very good news. Do you remember when the nurse injected that solution into your arm and you said that suddenly you felt much stronger?"

"Yes, I felt so much better, but only for a short time," replied Annie.

"That was the edrophonium test; we injected edrophonium chloride into your vein. It temporarily relieves weakness in people who suffer from myasthenia gravis. I am afraid that the diagnosis is confirmed by these lab results, which show an abnormally high level of antibodies in your blood."

Annie's mother asked about antibodies.

"Antibodies are part of your body's immune response; they are made when certain white blood cells encounter antigens; sorry, anything that is not you. In many cases of myasthenia gravis, the antibodies also compromise communication from your nerves to your muscles. One good piece of news is that the computer tomography (CT) scan shows that there is a tumor on your thymus gland. This tumor could be the reason for your problems. The thymus can be easily removed, and this will probably decrease the symptoms; it may even cure them. Additional treatment will probably be necessary to counteract the compromised situation between your nerves and muscles, and it may have to be modified depending on the results of the thyrectomy.

Questions

1. What is the role of the thymus in the body?
2. What is an *antigen*?
3. Go back to the flow diagram, look at each stage, and predict where the antibodies in Annie's blood could act to decrease synaptic function at the neuromuscular junction.
4. Neostigmine is one drug that may be prescribed for people with myasthenia gravis. This drug, like the edrophonium chloride injection, will make Annie feel stronger. Go back to the flow diagram, look at each stage, and determine how these drugs could work to increase synaptic performance.
5. In the absence of treatment, what has happened to the amplitude of Annie's endplate potentials as her disease has progressed?
6. Can you account for her progressive weakness?

Myasthenia gravis

- a disease involving the neuromuscular junction, is characterized by extreme muscular weakness. It is an autoimmune condition in which the body erroneously produces antibodies against its own motor end-plate ACh receptors. Thus, not all the released ACh molecules can find a functioning receptor with which to bind. As a result, AChE destroys much of the ACh before it ever has a chance to interact with a receptor and contribute to the end plate potential (EPP)
- Most commonly affected muscles are:
 - Face
 - Eyes
 - Swallowing (apparently swallowing is no longer a verb, but a muscle)

POP QUIZ — These questions could show up on a midterm/final (According to our TA):

NOTE: **RED** = Incorrect Option — **GREEN** = Correct Option

Question 1

Which of these statements applies to acetylcholine?

- |It destroys acetylcholinesterase| |It is blocked by sodium| |It is released from an axon terminal|
|It can be released from a postganglionic Sympathetic neuron|

Question 2

Which of the following applies to acetylcholinesterase?

- |It enhances activity from organophosphates| |It inactivates a neurotransmitter|
|It is a neurotransmitter| |It stimulates an excitatory postsynaptic potential|

Question 3

True or false? Clostridium botulinum toxin inhibits acetylcholinesterase?

|True|

|False|

(explanation: Botulinum destroys the NMJ)

Question 4

True or false? Acetylcholinesterase removes ACh from receptors?

|True|

|False|

***(Explanation: in tutorial, the only correct answer was TRUE. However, the wording is ambiguous. If we consider the question in terms of AChE removes ACh directly from receptors, the answer is FALSE. However, AChE indirectly removes ACh from receptors by inactivating the neurotransmitter. This process will indirectly remove ACh from their receptors)

Question 5

Which of these conditions occurs as the result of a lack of acetylcholinesterase in the synaptic cleft?

- |Decreased ACh Production by the motor neuron| |Relaxation of the muscle fibre|
|Inability of the motor neuron to stimulate the muscle fibre|
|excessive, continuous stimulation of the muscle fibre|