

Fluid in the Ear: A Case Study in Auditory Physiology

by

Jason W. Ho, Scott M. Leighow, Sylvie Lee, and Philip J. Stephens
Department of Biology, Villanova University, Villanova, PA



Part I – What’s Up, Doc?

Julius sat in the waiting room feeling lucky that there had been a cancellation. Dr. Luther had been his family physician for most of his life so there wasn’t much the doctor didn’t know about him.

“Hello Julius, how have you been?” asked Dr. Luther. “Is this a follow-up from your respiratory infection last week or are there other problems?”

“I think I’m getting better although the guys in the band tell me that I’m not hitting the high notes. I’ve been having bad headaches; the one today is really intense,” said Julius putting his hand to his head. “It feels like someone is pounding on my head with a hammer. I feel hot and nauseous and I have so much pressure in my ears that they feel like they’re going to pop. They’ve been ringing since the concert started last night; it usually goes away by now.”

“You know you shouldn’t drink alcohol when you’re taking antibiotics. How long have you been suffering with the headaches?” asked the doctor.

“On and off for a couple of weeks; since the beginning of the tour,” replied Julius.

“How’s your diet? Your chart shows that your weight has been dropping steadily over the past few months.”

“I’m trying to eat healthy, Dr. Luther, but with all these shows I don’t get much chance to sit down and eat, and when I do it’s usually fast food. Yesterday it was instant noodles and some beef jerky on the bus,” said Julius smiling.

Dr. Luther took off his glasses and looked straight into Julius’ eyes.

“I’m sorry to ask you this Julius, but have you been using? I know I’ve explained to you the effects that cocaine has on your body and I know you said you’ve stopped, but your symptoms are saying otherwise. It’s bad enough that you may be drinking while you’re on antibiotics, but putting cocaine into the mix can lead to some serious health complications. You have to be honest with me Julius, otherwise I can’t help you.”

“Dr. Luther, I swear to you I’m clean,” Julius said as he jumped up and stumbled a bit.

“I haven’t touched it in months... I think,” he said sheepishly. “My memory from last night is still a little hazy, but I promise you I’ve been trying to stay clean. I don’t know what’s wrong; that’s why I’m here Doc. What can I do?”

Dr. Luther let out a long sigh. “I’ll tell you what Julius, we’ll take some blood and run some tests to see what’s causing your headaches and ear problems. In the meantime, take some acetaminophen for the pain and keep taking those antibiotics for your respiratory infection; it sounds like you’re getting better. And remember, no more alcohol.”

“Thanks Doc.”

Questions

1. What problems is Julius experiencing?
2. Are any of these problems related?
3. What are some potential causes of these problems?
4. How could Julius’ eating and drinking habits cause or perpetuate his current symptoms?
5. What tests would you run on Julius? What results do you expect?

Part II – Don't Test My Patients

Table 1 – Partial List of Julius' Test Results

Test	Normal	Julius
Heart Rate (bpm)	60–100	90
Blood Pressure (mm Hg)	120/80	135/95
Blood [Na ⁺] (mEq/L)	135–145	146
Blood [K ⁺] (mEq/L)	3.5–5.0	4.5
Red blood cell count (million/ μ L)	4.7–6.1	5.2
White blood cell count (/ μ L)	4,500–10,000	13,000
Cocaine and narcotics		negative

“Well, your tests came back.” Dr. Luther closed the chart and placed it under his arm. “How are you feeling?”

“Not so great,” replied Julius. “I’ve been taking acetaminophen like you told me, but I feel worse. The ringing in my ears is getting louder and I’m feeling dizzy. I don’t understand, these headaches started a few weeks ago and have been getting worse by the day. I’ve cut down the partying and drinking.”

“You’re not 18 any more Julius. You can’t go on like this.”

“I’ll try to slow down, but for now I need to leave to get to the next show.”

Julius stood up, lost his balance and hit his head on the desk as he collapsed to the floor.

“Julius!” Dr. Luther jumped to his feet. “Julius, are you okay?”

Julius looked up at the doctor. “I can hardly hear you, Doc!”

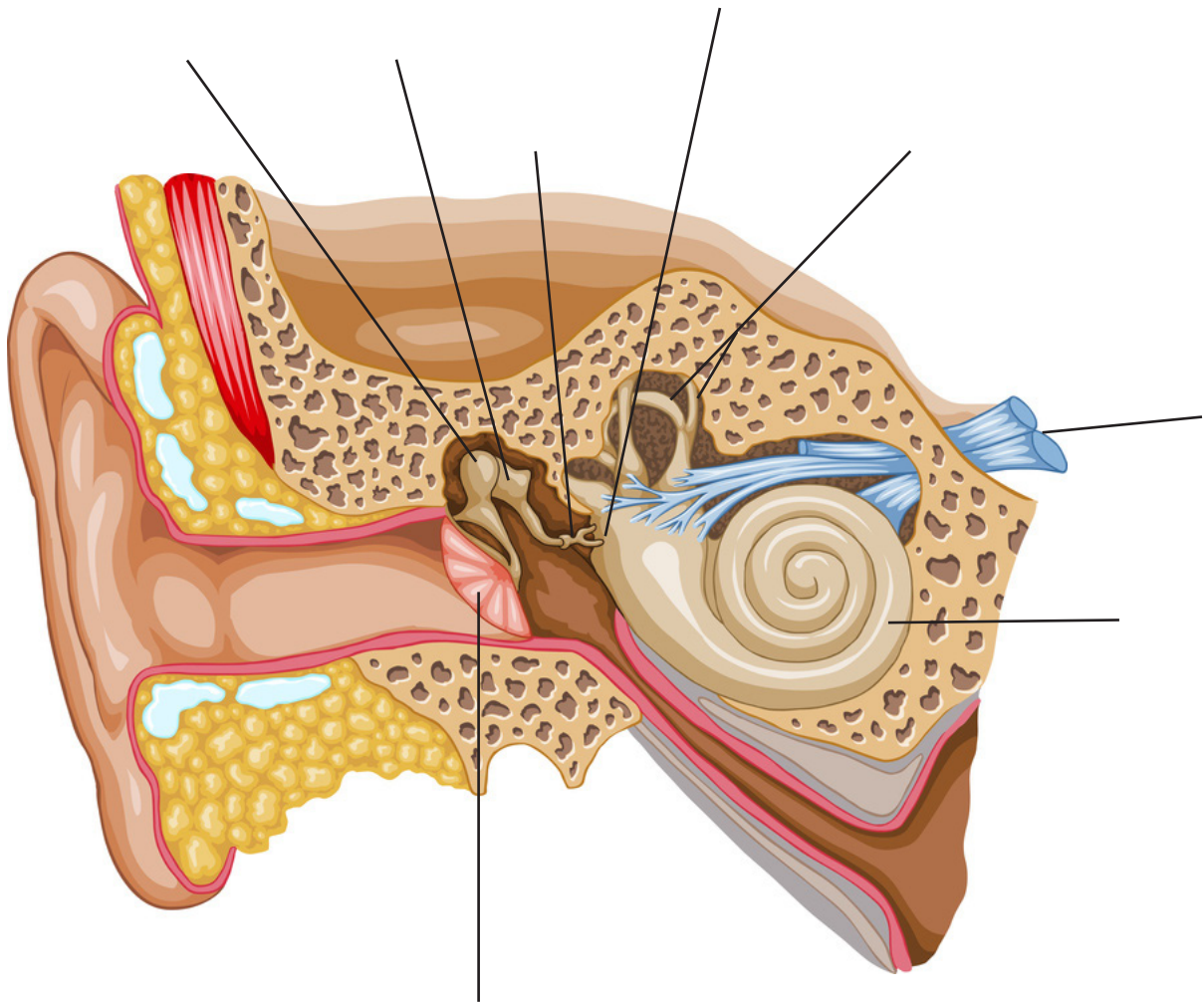
“We need to get you to the hospital!” said Dr. Luther, who then yelled for the nurse. Julius just stared back at the doctor with a panicked, unfocused look.

Questions

1. What new signs and symptoms is Julius exhibiting?
2. Look at the table above showing a partial list of Julius' test results. Which results are not within their normal range?
3. What may explain these abnormalities?
4. What is your preliminary diagnosis?
5. If you were the ER physician, what additional tests you would run? For each test predict the result.
6. Use the word list on the following page to label the diagram showing the anatomy of the ear (Figure 1).

Figure 1. Diagram of the inner ear and a word list for labeling.

Word List
Cochlea, Incus, Malleus, Round window, Sacculle,
Semicircular canals, Stapes, Tympanic membrane,
Utricle, Vestibulocochlear nerve.



Part III – What Could Possibly Go Wrong?

“Good morning Julius” said the doctor looking at the chart in her hand.

“Where am I?” asked Julius.

“I’m Dr. Shepard and you’ve been admitted into the hospital. Apparently you took a nasty spill and passed out in the doctor’s office.”

“Now I remember. My headaches have been getting worse and I felt dizzy.”

“Your hearing and balance complications come from problems with your inner ear so we’re keeping you here to do some tests to find out what is wrong with you,” explained Dr. Shepard.

“That takes me back to my undergraduate days,” interrupted Julius. “If I remember right, the cochlea is used for hearing and has something to do with balance.”

“That’s correct, Julius,” said the doctor. “Perhaps this wall chart will further jog your memory (Figure 2). It’s designed to illustrate the anatomy of the balance organs. See the semicircular canals, the utricle and the saccule; and it also shows the cochlea.”

“That’s the part responsible for hearing, right?”

“That’s correct, Julius, but what the diagram doesn’t show is the endolymph in the central canal running the length of the cochlea.”

“So the organs responsible for hearing and balance are connected and are bathed in the same solution, the endolymph. I guess that would explain why I’m having problems with both my balance and my hearing,” said Julius, feeling like he made a connection.

“That’s right,” answered the doctor.

Questions

1. The diagrams on the following page (Figure 3) show the structure of the cochlea and a cross-section. Use the word list provided to label the two diagrams.
2. Where in the cochlea are the hair cells, the sensory cells that detect sound?
3. What is the function of the *stria vascularis*, the cells that line the *scala media* or the cochlea duct?
4. The endolymphatic sac is a blind-ending structure connected to the cochlea and balance organs via the endolymphatic duct (see Figure 2 above). One function of the sac is to secrete endolymph back into the circulatory system. If Julius’ problem is produced by an increase in the pressure of the endolymph, what factors could contribute to an increase in the volume of this fluid?

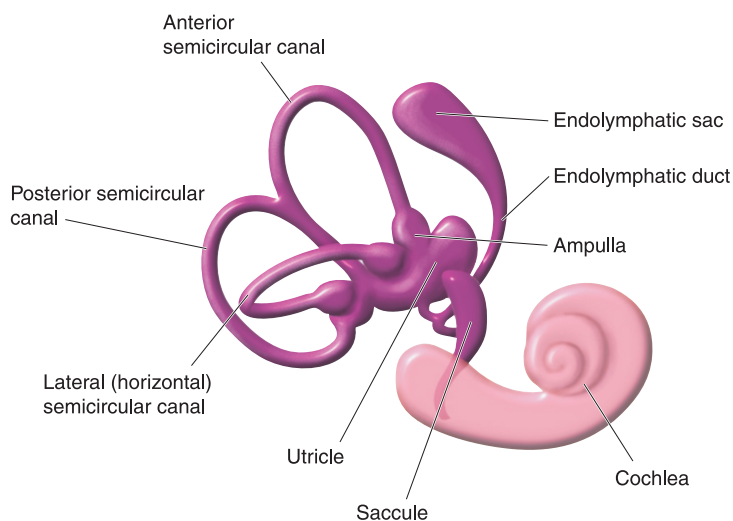
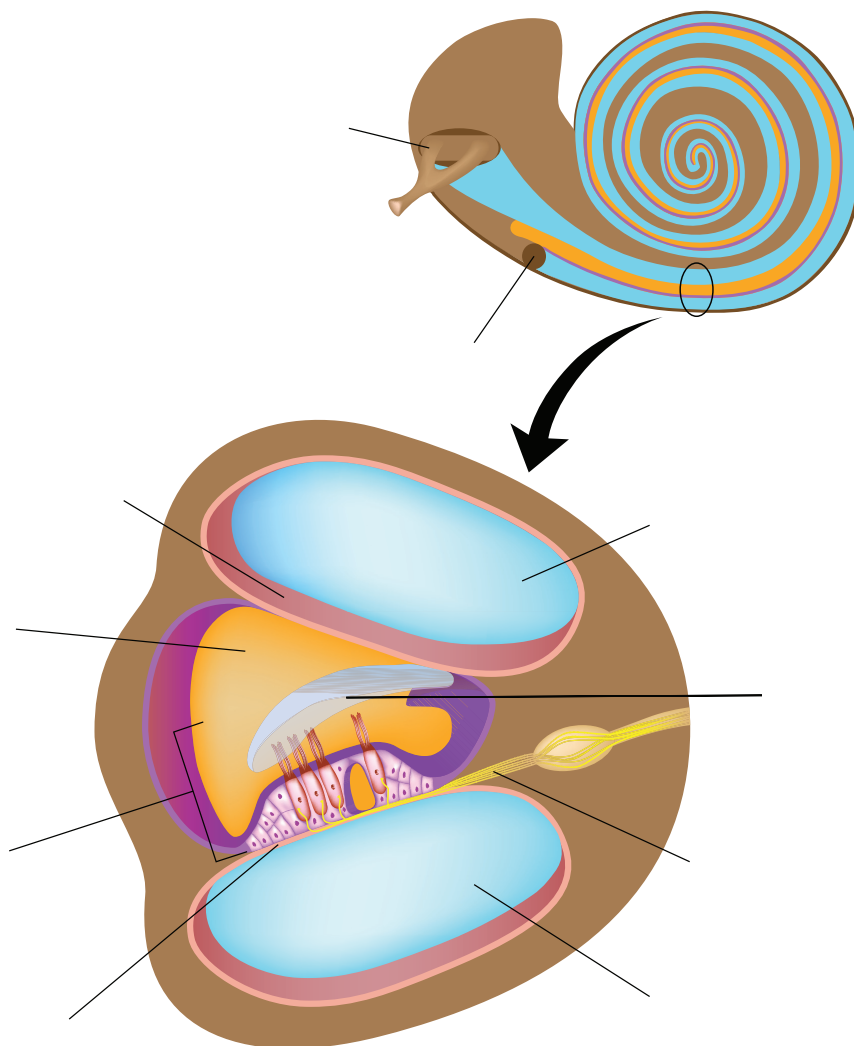


Figure 2. Anatomy of the balance organs.

Figure 3. Anatomy of the cochlea and a word list for labeling.

Word List

Basilar membrane, Cochlea nerve, Organ of Corti, Oval window (with Stapes), Round window, Saccule, *scala media* or cochlea duct (with endolymph), *scala vestibuli* (with perilymph), *scala tympani* (with perilymph), Semicircular canal, *stria vascularis*, Tectorial membrane, Utricle, Vestibular membrane.



Part IV – Rock On

“How are you feeling Julius? You gave me quite a scare,” said Dr. Luther.

Julius looked up at the drip hanging by the side of his bed and replied, “Much better, thanks.”

“Your chart indicates that your sodium levels are near normal and your blood pressure is coming down into an acceptable range.”

“So what’s wrong with me, Doc? Am I going to be alright?”

“At this point we’re trying to rule out possibilities. First, the MRI showed no brain tumors.”

“That’s a relief.”

“However we see swelling of your labyrinth and endolymphatic sac in your inner ear so we think you may be suffering from Meniere’s disease.”

“What’s the cause? Did I catch something? Can it be cured?”

Doctor Luther looked around the room and spotted the wall chart used by Dr. Shepard to explain the connection between balance and hearing (Figure 2).

“The cochlea and balance organs have two fluids: perilymph and endolymph. Now, as a biology major I’m sure I don’t have to remind you about interstitial fluid; the fluid that bathes your cells.

“Yes, I remember that,” replied Julius.

“Well, the composition of perilymph and interstitial fluid are similar.”

“So what’s endolymph?” asked Julius.

Endolymph is found in the *scala media* of the cochlea.” Dr. Luther pointed to the central canal in the section of the cochlea (Figure 4). “It has a very high level of potassium and bathes the sensory or *hair cells* in the cochlea and the balance organs. Now, this solution is constantly secreted by cells along the length of the cochlea called the *stria vascularis*.” Dr. Luther pointed to the area lining the central canal of the cochlea.

“Clearly this secretion of endolymph cannot go on unchecked otherwise the pressure would increase and the structure would burst. Under normal circumstances, while much of the potassium is recirculated back to the cells of the *stria vascularis*, much of the endolymph passes through the endolymphatic duct and into the endolymphatic sac, where it is reabsorbed back into the body’s circulation.” Dr. Luther pointed back to the diagram of the cochlea and balance organs (Figure 2).

“I guess there’s a balance between secretion and reabsorption so the *volume* stays the same? No pun intended, Doc,” said Julius with a smile on his face.

“Right,” said Dr. Luther smiling. “We believe that the drainage of your endolymph may be compromised. This could be due to something as simple as an inflammation of your endolymphatic duct. If this is the case then the volume of your endolymph in the *scala media* increased and this would have produced the ringing sound and your balance problems.

“How would a buildup of fluid produce sound?” asked Julius.

“The hair cells in the cochlea are stimulated by pressure differences created by sound. If fluid accumulation increases the pressure in the *scala media* then your hearing would be affected.”

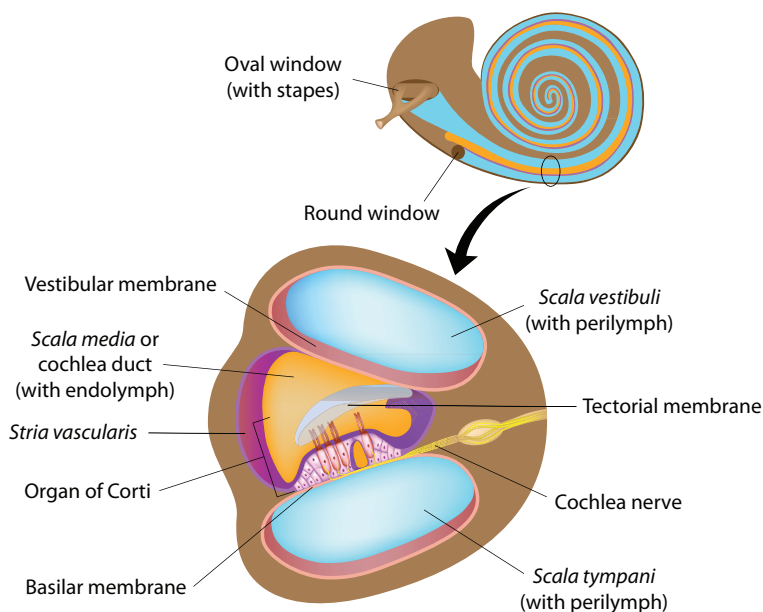


Figure 4. Anatomy of the cochlea.

“So why did things get worse when I fell over in your office?”

“We think that your fall may have damaged the vestibular membrane in your cochlea; it’s the membrane between the *scala media* and the *scala vestibuli*.” Dr. Luther paused as he pointed to the wall chart. “We think that the membrane may have become stretched by the increase in fluid pressure, and the fall was enough to rupture it. As a result the perilymph and the endolymph mixed and this affected your hearing.”

“That sounds serious, Doc.”

“It can be, but membrane damage is often repaired quickly and the solutions return to normal. The fact that you can hear me now is a very encouraging sign and indicates that the membrane may have healed already. But you may need more time to fully recover.”

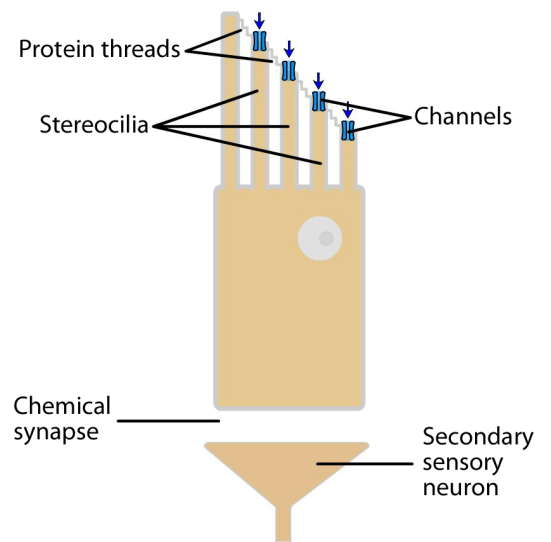
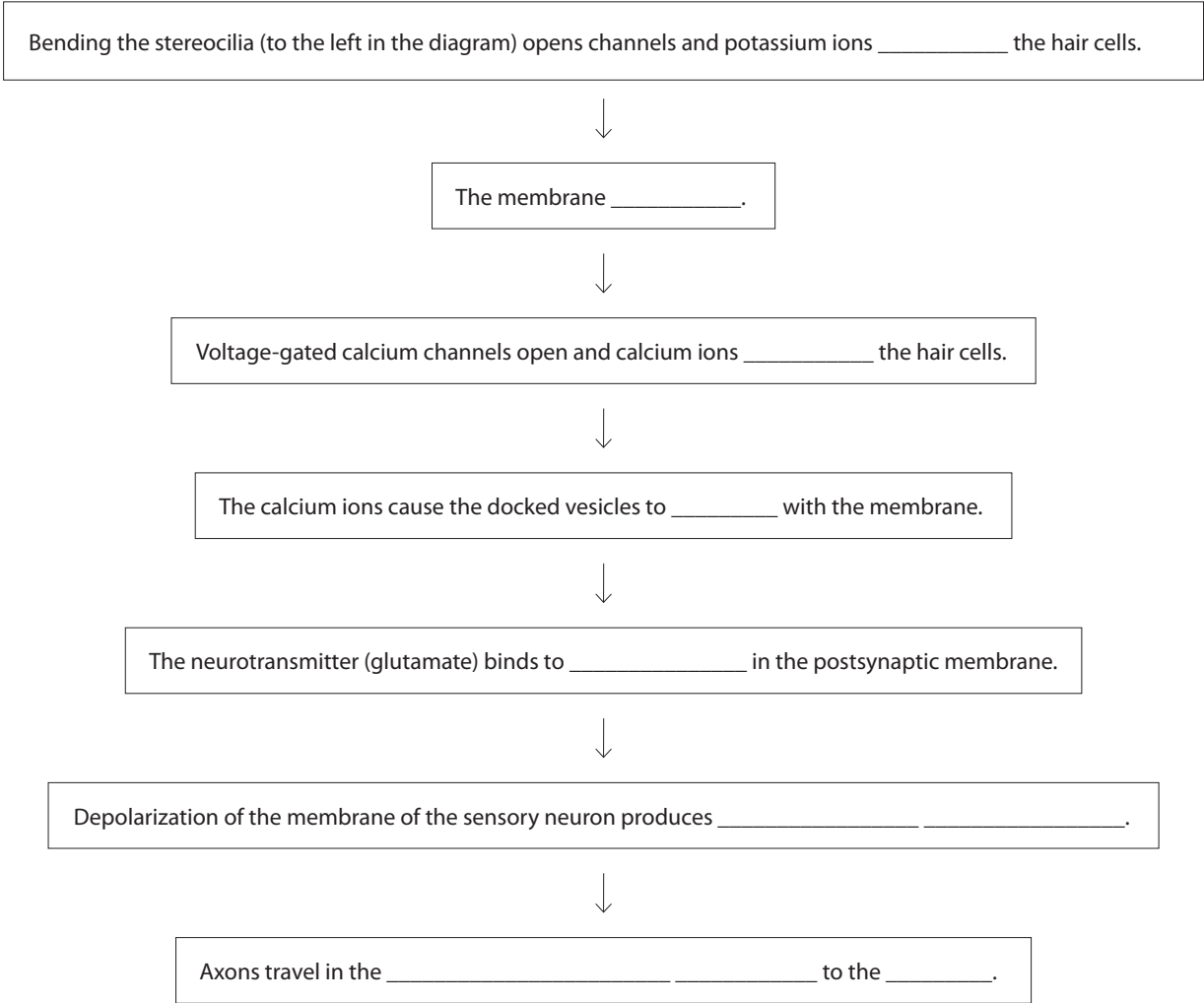


Figure 5. Hair cell.

Questions

1. Remembering that the level of potassium in the endolymph is higher than inside the hair cell (Figure 5), use the following word list to fill in the flow diagram below: *action potentials, brain, cochlea nerve, depolarizes, dock, enter, fuse, hyperpolarizes, leave, membrane, receptors.*



Part V – Recovery

Julius went through a series of tests by the resident otolaryngologist before being discharged into his parents' care. A few weeks later he returned to Dr. Luther for a checkup.

“Well Julius, I’m pleased to learn that you no longer feel dizzy. However, the audiogram indicates that you still have problems hearing certain frequencies.”

“What does that mean for my career? I’m not too sure there are many tone-deaf singers out there!”

“It’s a little soon to tell, Julius; there may not be too much permanent damage. If there is, there’s nothing we can do to cure you; you may have to live with this problem and just manage your symptoms. In some people this is a genetic problem, but you say that there is no history of Meniere’s disease in your family. In this recent episode I believe that it is likely that the infection sparked inflammation of the endolymphatic duct in your ears, which decreased fluid drainage and resulted in a higher pressure. However, your original blood test showed slightly elevated sodium levels and this can cause water retention and may increase endolymph production,” said Dr. Luther.

“Living with your parents these last few weeks certainly has improved your health and your energy levels. Now, I know a guy of your age doesn’t want to live with Mom and Dad but it seems you’re going to have to get your act together and start taking better care of yourself and eating healthier. I’m sorry to say this, but living like a rock star just isn’t a viable option for you anymore.”

Questions

1. The audiogram indicates that Julius has problems hearing certain frequencies. What type of damage may have taken place in Julius’ ear?
2. Would this damage have necessarily taken place in both ears?
3. If you were the doctor, what life style changes would you recommend to Julius?



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