

A “Deafinite” Cause for Alarm: A Case Study in Hearing Physiology

by

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Part I – Bacterial Pneumonia

The doctor entered the room to find the television blaring and Henry counting ceiling tiles.

“Dr. Robertson, I’m tired of lying in this uncomfortable hospital bed; when can I go home?”

“Bacterial pneumonia is nothing to be taken lightly, Henry; it can even be fatal, especially for a person in their 60s. I’m sorry, but we need to continue monitoring you until you have finished your treatment.”

Henry shifted in his bed and stared out the window, missing the sunshine that he hadn’t been able to feel on his face in almost a week.

“But Doc, the cough has gone and I feel fine. Can we at least get this thing out of my arm?”

“Sorry, Henry, but you still have three more days left on your treatment. An IV drip is the most efficient way to maintain the level of the antibiotic required to attack the bacteria in your lungs.”

Henry waited until everyone had left the room before he reached over to the pump and pushed the plunger on the syringe.

“Maybe if I get this juice faster, it’ll speed the process and get me out of here,” Henry mumbled.

Questions

1. What signs and symptoms did Henry experience?
2. What was the initial diagnosis for Henry’s problems?
3. What treatments were given to Henry in the hospital?
4. Why was it a bad idea for Henry to increase the drip flow rate?

Part II – A Walk in the Park

“I forgot to lock the syringe pump and that was my fault, but a man of your age should know that you’re not supposed to touch your meds, Henry. You got me into a lot of trouble,” said the young nurse. “I just graduated and I already have a black mark on my record.”

“Sorry, Laura, but I thought if I got more antibiotics the infection would go away faster and I’d be able to go home sooner.”

“How is our problem child today?” asked Dr. Robertson as he entered the room.

“Hi, Doc. Please don’t be mad at Nurse Laura. It wasn’t her fault; it was all me,” said Henry.

“Our first duty is always your health and safety, Henry. Gentamicin is a very strong antibiotic and it can do physical damage if administered at too high a dose. Please, we don’t want to have someone in this room to watch you 24/7, so can we trust you not to do that again?”

“Apparently you’ve locked the syringe pump so I can’t change the drip anyway, and Nurse Laura comes around every hour to check on me so I don’t think I could do anything even if I wanted to. Don’t worry, it won’t happen again,” Henry responded. “But I am feeling claustrophobic, Doc. Do you think there’s any way I could go outside and sit in the sun for a while?”

“I guess so, Henry, but you will have to be taken in a wheelchair. You can stay in the garden for a short while, but you will need to rest when you get back; your body is still weak from fighting the pneumonia.”

Dr. Robertson left the room and returned with an orderly and a wheelchair. Freddie, Henry’s son, and the nurse stood by Henry’s bedside, but Henry stubbornly refused their help. Upon standing, Henry stumbled and collapsed.

“Be careful; gently now, Henry,” said the nurse.

Henry slowly stood, twisted at the waist in an attempt to sit in the wheelchair and said “I’m feeling really dizzy.”

Henry fell to the floor and lost consciousness.

“We need to get him back into bed!”

Questions

1. List the signs and symptoms that Henry experienced.
2. What usually happens to your heart rate when you sit or stand from a lying position?
3. What happened to Henry when he stood up?
4. Explain what happened to Henry’s blood pressure when he stood up.

Part III – An Alarming Situation

Henry's release from the hospital was delayed by a few days because of his loss of consciousness. The doctor explained that Henry most likely fainted because of a drop in blood pressure when he stood. He had been out of the hospital for about two weeks since that episode and every day he felt a little stronger.

Freddie had stayed with his father since his release from the hospital to take care of Henry and make sure that he took the oral antibiotic prescribed by the doctor.

"Dad, it's probably about time for you to get ready for bed."

Henry did not respond to his son's suggestion.

"Dad? I said you should probably be getting ready for bed!"

"You did? I'm sorry, son. My ears have been ringing ever since I got out of the hospital. I must be going deaf. I think I'll go to bed."

"Goodnight, Dad. See you in the morning."

Freddie woke in the morning to his father's alarm ringing in the room down the hall. He got out of bed, showered, dressed, and noted that his father's alarm was still ringing. He walked into Henry's bedroom and nudged him awake.

"Dad, don't you hear the alarm? It's been ringing for the past 20 minutes. You were supposed to wake up to take your antibiotics."

Henry blankly stared back at his son, confused and panicked. Freddie turned off the alarm clock.

"Dad, what's wrong with you? Are you deaf?"

"Freddie, quit messing..."

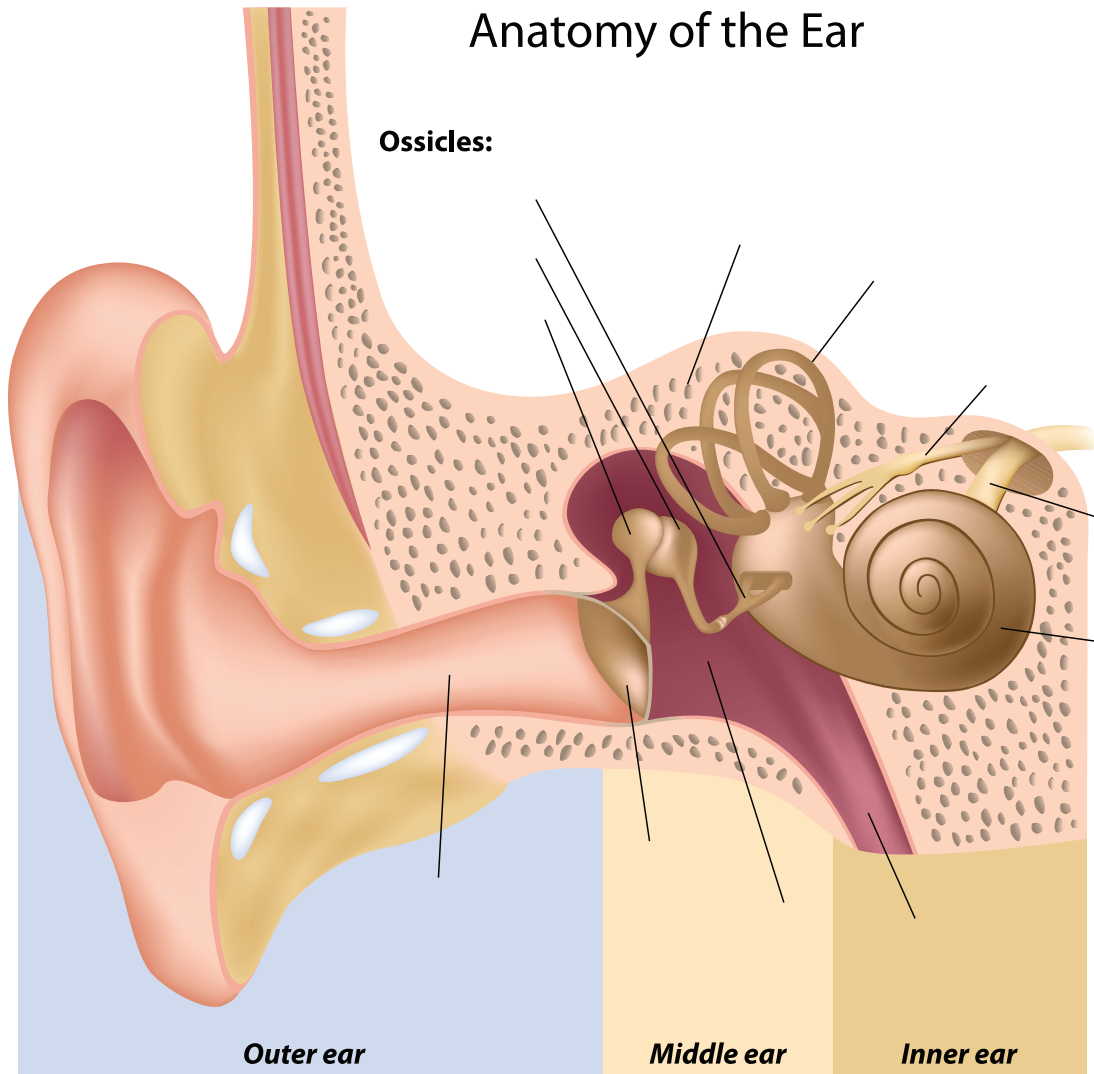
Henry froze mid-sentence, realizing that he couldn't hear his own voice.

Recognizing that his father was unable to hear him, Freddie quickly helped Henry get dressed and got him into the car. In a panic, the two raced to the Emergency Room.

Questions

1. List the new symptoms that Henry experienced while at home.
2. Use the word bank to label the ear diagram on the next page.
3. Use the diagram to determine what structures could be responsible for Henry's hearing loss.
4. Use the internet to determine the types of tests that could be conducted to diagnose Henry's problem. For each test predict the results for Henry's condition.

Anatomy of the Ear



Word Bank: auditory canal, Eustachian tube, cochlea, cochlear nerve, incus, malleus, stapes, semicircular canals, temporal bone, tympanic cavity, tympanic membrane, vestibular nerve.

Part IV – The Emergency Room

Freddie paced back and forth in his father’s room patiently waiting for the results of Henry’s diagnostic tests. After what seemed like forever to Freddie, a nurse and the attending ER physician arrived to talk with him.

“Freddie? Thanks for being so patient; I’m Dr. Samantha Nelson. Let’s talk about the results of your father’s tests. His vitals and visual responses were normal for a person of his age, and his ears showed no signs of any physical blockage. His blood panel was normal as well.”

Freddie nodded as Dr. Nelson began explaining the results of Henry’s auditory tests.

“I’m afraid that your father performed below average on all of the auditory tests performed, as we expected would be the case. However, there were some promising signs.”

Freddie looked at Henry, who was nervously glancing back and forth between the doctor and the results that he had in his hands.

“The auditory specialists ran several tests including a pure tone audiometry test; this assessed Henry’s ability to hear sounds of varying pitches or frequencies and volumes. He was unable to hear tones at high and low pitches and could only hear intermediate frequencies when the volume was high.”

Freddie tried not to appear concerned, so as to not make his father even more nervous.

“Okay, what’s wrong? Can it be fixed?”

“It seems that your father’s cochlea has suffered some physical damage so he can only hear loud sounds at intermediate frequencies.”

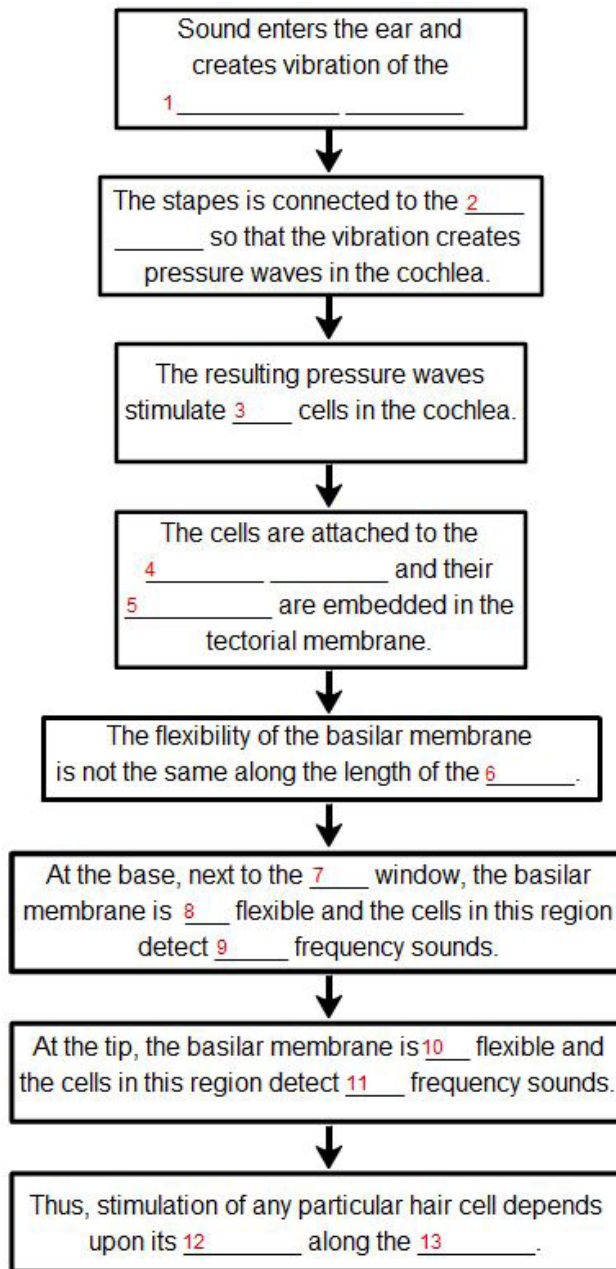
“What’s a cochlea?”

Doctor Nelson took Freddie’s tablet and found a website. “Maybe you should take a look at this video clip if you want to know more about hearing.”

- *2-Minute Neuroscience: The Cochlea*, produced by Neuroscientifically Challenged, 2015.
<<https://youtu.be/WeQluId1hnQ>>.

Questions

1. Henry’s blood panel was normal, including his white blood cell count. What does this indicate about his original infection?
2. Complete the flow diagram on the next page.
3. For each answer in the flow diagram explain how damage could influence Henry’s ability to hear different frequency tones.

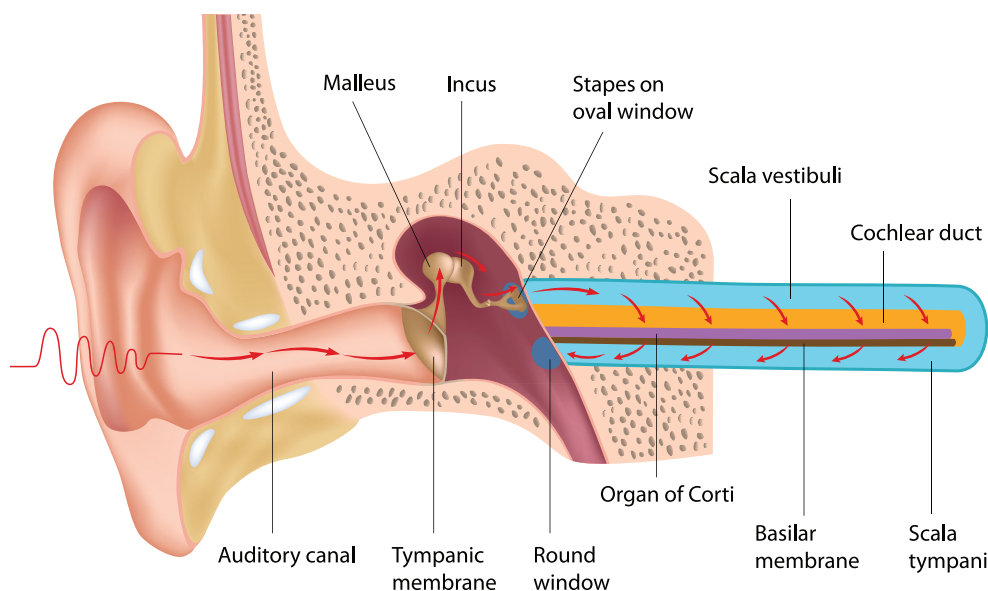


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Part V – Ototoxicity

After listening to Dr. Nelson explain the test results, Freddie knew his father’s hearing loss was the result of damage to the sensory cells inside the cochlea, but he still wasn’t sure how it happened. As if reading his mind, Dr. Nelson walked back into Henry’s room.

“We believe that your father’s hearing loss may have been a side effect of the gentamicin given to him for his bacterial pneumonia. Henry’s doctors took precautions to keep the level of the antibiotic high enough to combat his infection but not too high to do any physical damage. We believe that when Henry increased his dose it elevated the amount of antibiotic in his system where it entered the inner ear and damaged the sensory cells; take a look at this chart on the wall.



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“When sound enters the ear it causes the stapes to push against the oval window. This creates a pressure wave that travels down the fluid in the scala vestibuli,” said the doctor pointing to the upper blue region in the diagram. “This tube-like structure travels the length of the cochlea and connects to the lower blue tube on this diagram, called the scala tympani. So the pressure wave could pass back down the other side of the cochlea to produce compensatory changes in a structure called the round window.”

“So where are the sensory cells you talked about?” asked Freddie.

“The sensory or hair cells are located in a third, central tube, which is colored yellow,” said the doctor still pointing to the diagram. “As the pressure waves move along the outer tubes they tend to move the central tube up and down, as shown by the arrows. These tiny movements stimulate the hair cells, which are attached to the basilar membrane, and produce the sensation of hearing.”

“Wow, that’s a lot to absorb in one sitting,” said Freddie.

Questions

1. Which frequencies can Henry not hear?
2. Where are the cells responsible for detecting these frequencies located in the cochlea?
3. What part of Henry’s cochlea may have damaged hair cells?
4. What part of Henry’s cochlea may have functional hair cells?

Part VI – Tone Deaf

“I understand that sound is converted to pressure waves in the fluid in the ear, but how is this perceived as sound?” asked Freddie. “How do these hairs cells work?”

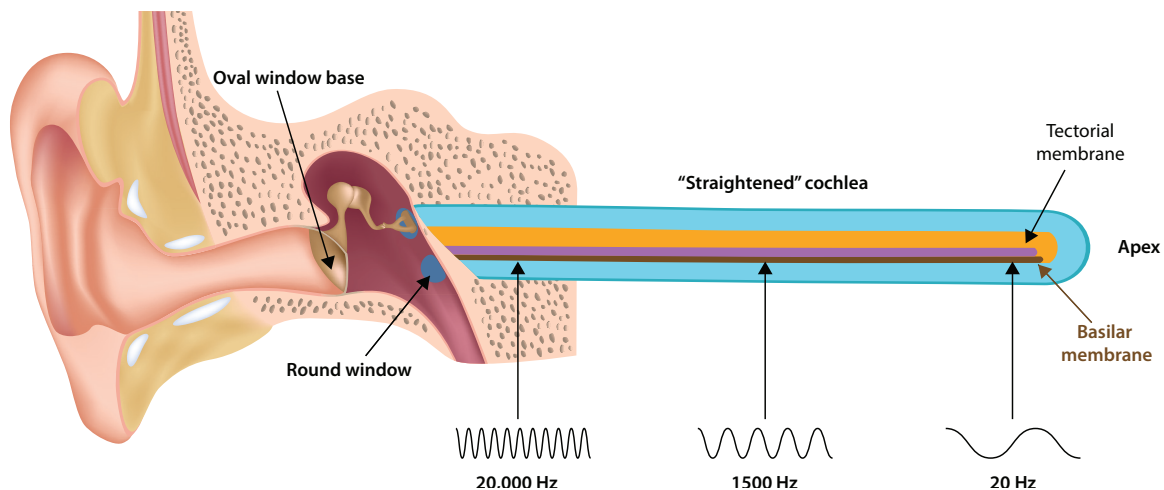
“Here, why don’t you take a look at another video clip,” replied the doctor: [hair_cells_video.mp4](#) (click to view).

“Unless I missed something, there must be more to this story because I don’t understand how Dad can hear some sounds and not other; and why does the volume have to be turned up for him to hear?”

“Second part first, Freddie” replied the doctor. “We believe that some of Henry’s hair cells have been damaged, and some may have even died as a result of the high level of certain antibiotics. This is why it is important that antibiotics, like all medicines, should be taken as directed. Unfortunately you father did not do this, with the result that he did some serious damage to his hearing. He does have some functioning hair cells but because they are so few in number they take more stimulation to excite, which is why he can only hear loud sounds.”

“But why can he hear some sounds and not others?” asked Freddie.

“While the hair cells in the cochlea are all the same they respond to different frequencies; this can be explained by properties of the basilar membrane, the structure the hair cells are attached to. At the base of the cochlea, next to the oval and round windows,” said the doctor pointing to a second diagram on the wall chart, “the basilar membrane is thin and flexible. Cells attached to this part of the membrane are stimulated by high frequency sounds. At the other end of the cochlea, at the apex, the basilar membrane is less flexible so hair cells in this area are stimulated by low frequencies.”



“So you’re telling me that these hair cells are found along the length of the cochlea, and that the hair cells in different locations detect different frequencies?”

“Absolutely correct, Freddie, you catch on fast,” replied the doctor. “Now we need to do more tests on your father’s hearing to make sure that our diagnosis is correct.”

Questions

1. During an action potential in an axon, which ion channels open to depolarize the membrane?
2. In the ear, which ion channels open to depolarize the membrane of the hair cells?
3. Henry can only hear sounds of intermediate frequencies; not high and low frequency sounds. If his hearing loss is due to hair cell damage, where along the cochlea are these damaged hair cells?
4. Assuming that the doctor’s diagnosis is correct, what treatments would help restore Henry’s hearing?