Neurons (nerve cells that send and receive electrical signals in the body) in specialized regions of the brain are responsible for our ability to hear. However, in order to interpret both simple and complex sounds, such as speech or a note on a piano, a subset of these neurons must respond in synchrony (occur at the same time) with the temporal rhythms and oscillations (repeating fluctuations) of brain activity.

By analogy, in an orchestra comprised of millions of musical neurons, the music of Beethoven will only emerge from the neural activity when all the members of the "orchestra" follow the tempo of the musical passage. Individual members of the orchestra must carefully listen to the ever-evolving musical theme and react appropriately to maintain the melody.

The role of brain rhythms

For more than a century, researchers have been recording brain rhythms in an attempt to understand how the brain processes sensory information. They have segregated the rhythms of the brain into several classes by the frequency with which they occur. Some frequency bands are associated with specific activities. For example, when you close your eyes, an alpha rhythm (10 Hz) will be generated from the visual processing areas of your brain located at the back of your head. The alpha rhythm seems to be important for maintaining order over large areas of the auditory, visual and somatosensory cortex. Gamma rhythms, which occur at higher frequencies (30-60 Hz), typically develop when a new sensory signal (sound, sight or touch) arrives at the cortex. The strength of these bands is constantly changing as we attend to, or ignore, the sensory signals coming in from the environment. The relative strengths of alpha and gamma band brain waves can tell us much about what the brain is processing or attending to.

Brain rhythms and tinnitus

Within the past few years, researchers studying tinnitus have noticed that even in quiet, the brain areas that process sound in people who suffer from persistent tinnitus have proportionally less strength in the alpha rhythm and more in the gamma rhythm than those who do not suffer from tinnitus. This pattern of activity is very similar to those that occur when your brain receives a sound from the environment. In our research using animals with noise-induced or drug-induced tinnitus, we noticed a pattern very similar to that recorded from humans suffering from tinnitus (Fig. 1, page 13). The broad goal of this research project is to understand how small groups of neurons, as well as individual neurons (the individual musicians) change their interpretation of the entire orchestral piece to give rise to tinnitus.

Why rhythms may change

One possible reason why these rhythms change their pattern of communication during tinnitus may be a loss of normal sound input due to noise trauma, drug toxicity or age-related hearing loss. When the brain loses normal input from the ear, the brain tends to adjust to make it better able to detect any input that may still be available. In doing so, individual neurons may receive messages from other neurons they normally would ignore.

Awake and alert

An important aspect of my research is obtaining measurements related to tinnitus rats that are awake and conscious. During sleep or anesthesia, we do not normally perceive sounds from the environment or the internal phantom sound of tinnitus. Therefore, I obtain all of my measurements of brain rhythms, before and during tinnitus, from conscious animals.

Over the past few years, I have developed the techniques to record from unanesthetized rats for up to several months. Although technically challenging, my results are likely to provide a better understanding of how changes in brain rhythms contribute to the perception of tinnitus and what brain regions may be involved. A major component of my efforts during the past year has been developing custom computer software to pick out the activity of single neurons from the cacophony of activity from thousands of other surrounding neurons and to relate the neural activity to changes in the brain’s rhythm.

Aspirin and neuronal changes

I present here some of the first data to come from this project (Fig. 2, page 13). We gave an awake rat a high dose of aspirin, a drug known to reliably induce tinnitus. A small group of neurons responded in the
rat’s auditory cortex before (left) and one hour after (right) inducing tinnitus. These figures represent the ongoing rhythmic activity in the rat’s auditory cortex that occurred just before (-1 to 0 seconds) and just after (0 to 1 seconds) the neuronal response.

In an animal without tinnitus, energy in the alpha band (8-12 Hz) decreased during the neuronal event (occurring at 0 on the bottom axis), while other frequency bands, such as theta (4-7 Hz), increased. During the neuronal event, the energy in the alpha band decreased. Other frequency bands, such as gamma (30-60 Hz) and beta (12-30 Hz), seemed to increase.

Thanks to the generous support of ATA, I now have the technology, tools and experience to better study the neural underpinnings of tinnitus in awake animals. In addition, this research will allow us to test the efficacy of drugs and other forms of treatment to alleviate tinnitus.

Daniel Stolzberg is a Ph.D. student under the mentorship of Richard Salvi, Ph.D., at the Center for Hearing & Deafness, University at Buffalo, The State University of New York.