Good afternoon. As Dr. Matthews stated, I am Ron Kirkland, a local Otolaryngologist. That’s Greek for ear and throat specialist. The Greek title is an example of the philosophy that if your specialty has a long title that is hard to pronounce, you can charge more for your services. That’s why I really like Otorhinolaryngologist even better.

I earned my MD degree from the University of Tennessee at Memphis, and my specialty training was mainly in Memphis as well, finishing in 1982. I was board certified later in 1982. After two years of practice in Memphis, my wife, four children and I moved to Jackson to join The Jackson Clinic where I continue to work today.

My charge from Dr. Matthews is to provide you with basic information regarding the maintenance of hearing health and safety, to include injury prevention, within the contexts of practice, performance, teaching, and listening. For many of you, parts of this presentation will be very familiar, but here’s hoping that some of what I present will be fresh and interesting.

We’ll go for 45 or 50 minutes of interactive presentation, and then have some time for questions.

As the outline shows, we will have 3 main parts. First the anatomy and physiology of the ear. Dull, boring, but necessary. Second the physics of sound. Again dull, boring, but necessary. Third the possibility of injury when
you put your ears and sound together. Maybe just a little more interesting.

The human ear is truly a remarkable organ and we have two of them. Anyone know why we have two ears?

As one who believes in Divine Creation, I know the answer is that God made us that way. But why would He do that?

One reason is that if we lose one, we have a spare. Also so that we have stereo hearing that will allow us to localize sound. Like the incoming mortar rounds that I heard while in Viet Nam – not that hearing them made me any safer, because you didn’t hear the ones that were coming right at you.

Did you ever stop to think that we are able to localize sound horizontally much easier than we can vertically? Anyone know why? Because of the symmetrical position of our ears on our heads. Some owls have asymmetrically placed ears that allow them to localize sound vertically. Perhaps that’s why dogs tilt their heads when you talk to them?
THE ANATOMY AND PHYSIOLOGY OF THE EAR

Let’s break the ear down into its parts – the outer ear, the middle ear, and the inner ear.

The outer ear comprises the fleshy part known as the auricle, or pinna, plus the ear canal that leads to the eardrum or tympanic membrane, and the outer surface of the tympanic membrane itself. Yep just like the tympani in the orchestra – even to the point that the tympanic membranes can be made very tight if a very intense sound is presented. There are tiny muscles in the middle ear that attach to the hearing bones or ossicles. These tiny muscles contract and stop the ossicles from vibrating when exposed to a very loud sound. In the military, just before an artillery piece shoots a shell, a high pitched sound is projected to everybody’s ears nearby which causes these tiny muscles, the stapedius and the tensor tympani, to contract, causing sound to be reflected by the tympanic membranes rather than absorbed. But I digress.

The middle ear comprises the inner side of the tympanic membrane, the ossicles, the oval window, and the middle ear space including the Eustachian tube which connects the middle ear to the back of the nose, or nasopharynx. The eustachian tube is the culprit when your ears pop on an elevator or in an airplane.
Try this – hold your nose and blow to try and pop your ears. You’re forcing air into your middle ears through your Eustachian tubes. Before taking an airplane flight or going scuba diving, you should be sure you are able to do this maneuver. It may be difficult if you have a cold or any head congestion.

Under normal circumstances the tympanic membrane vibrates from the sound presented and moves the ossicles, which then move the inner ear fluid through the oval window. The ossicles are the smallest bones in the human body with the stapes winning the prize as the very smallest bone in our bodies.

In one particular disease process, the stapes can become fixed in place rather than mobile, causing significant hearing loss. Fortunately for those so afflicted, there is an operation available where an ear surgeon can work using a microscope to operate and replace this tiny bone with an artificial stapes that then moves freely and re-establishes the transmission of sound energy to the inner ear.

The inner ear is a tiny collection of tubes and sacs that are filled fluid. These tubes and sacs have names like semicircular canals, cochlea, and vestibule. When the tympanic membrane moves, or vibrates, the fluid in the cochlea moves or vibrates, and this in turn makes tiny cilia
on the surface of the hair cells move on the basilar membrane, and that in turn creates electrical stimulation to the brain where it is interpreted as sound. It is damage to these hair cells that causes irreversible noise related hearing loss. The semicircular canals actually have similar structures that move with rotation, and in the vestibule that move with acceleration, again sending electrical stimulation but this time it is interpreted by the brain as movement and the brain takes action to keep us stable.

The inner ear is one of the most delicate areas of the human body, rivaling the eye for complexity. Let’s look briefly at the balance function of the inner ear, where any movement of the tiny cilia in the vestibule and in the semicircular canals allows gymnasts to walk a balance beam, and for that matter allows us to just walk across the floor.

But balance is not one of our topics for today. I mention it only to point out that the anatomy and physiology of balance are very similar to that of what we are here to learn about - hearing.

And for that we move to the cochlea, a spiral structure with precisely 2.7 turns, made up of internal channels, including a basilar membrane covered with hair cells. So
sound enters the ear canal, causes the tympanic membrane to vibrate which in turn causes the ossicles to move back and forth, which then causes the fluid in the cochlea to move back and forth. As the fluid is rhythmically compressed through the oval window, the pressure is released by bulging at the round window back into the middle ear. Almost like working out on a stair climber. The bone surrounding the cochlea, vestibule, and semicircular canals is the hardest bone in the body, and is called the otic capsule.

THE PHYSICS OF SOUND

Sound is a mechanical wave that is an oscillation of pressure transmitted through a solid, liquid, or gas, and it is composed of frequencies within the range of hearing. Sound cannot travel through a vacuum.

And what is the difference between sound and noise? Noise is simply unwanted sound. So all noise is sound, but not all sound is noise. You might say, “One person’s noise is another person’s sound”.

One characteristic of sound is loudness.

The decibel is commonly used to quantify or measure the loudness of sound with a 0 dB reference. Zero dB is the quietest sound a human can hear. This is roughly the sound of a mosquito flying 3 yards away. The ear is exquisitely sensitive to sound. We can hear vibrations of the eardrum of less than one tenth the width of a hydrogen atom!

The human ear has a wide dynamic range to perceive sound. The sound intensity that causes permanent damage during short exposure is about 1 trillion times the quietest sound that the ear can hear. These large measurement ranges are most conveniently expressed in logarithmic units, and dBs are expressed in logarithms.

There are different units associated with the measurement of the loudness of sound. For example, sound intensity is not the same physical quantity as sound pressure. But I’m not enough of a physicist to explain the difference to you. Let’s just agree that it is difficult to understand the measurement of loudness of sound.
Another characteristic of sound is pitch or frequency. For humans, hearing is normally limited to frequencies between about 20 Hz and 20,000 Hz. One hertz is one cycle per second.

Some sounds can be measured but cannot be detected by the human ear. For example, people cannot usually hear bats when they communicate at very high frequencies, or whales when they use very low frequencies.

The ear is also very good at separating out the different frequency components of a sound. Each location on the basilar membrane is tuned to a different frequency so that low-frequency sounds cause the membrane to vibrate near the top, or apex, of the spiral, and high-frequency sounds cause the membrane to vibrate near the bottom, or base, of the spiral. Each nerve cell or neuron in the auditory nerve is connected to a single site on the basilar membrane, so that information about different frequencies travels to the brain along different neurons.

For a moment let’s compare the ear with the eye. The human eye can distinguish just three basic colors: red, blue, and yellow. The vivid sensation of color we are able to experience is made up of combinations of just these three colors. The ear, on the other hand, can separate up to a hundred different sound frequencies, corresponding to the number of frequencies that can be separated by the
basilar membrane. We get a much more detailed experience of the “color” of sounds, the timbre, than we do of the color of light. This is how we can tell the difference between two different instruments playing the same note, for example, a French horn and a cello. Although the pitch of the two instruments is the same, the timbre is different, and our ears can quickly tell the difference. For a period of time in high school and in college I played, if I may be generous in the use of the word “played”, the bassoon. And to me, that is still the most easily recognizable tonal instrument in the orchestra.

The deeper understanding and appreciation of pitch, and timbre, and the emotion of major and minor keys are beyond my understanding and will be left to Dr. Matthews and his department.

And isn’t it amazing that our ears, and brains, can be in the center of many different sounds, and yet we can selectively pick out the sound of one voice to follow in a conversation, or can selectively pick out the sound of one instrument in the orchestra? And how do our ears and brains actually hear the complex blend of a symphony?

http://www.youtube.com/watch?v=9hUy9ePyo6Q
Simon and Garfunkle
So again, how do we hear?

1. Sound waves arrive at the tympanic membrane or eardrum.

2. The vibration of the tympanic membrane causes movement of the ossicles.

3. The movement of the stapes at the oval window creates pressure waves in the fluid of the cochlea.

4. The pressure waves distort the basilar membrane on their way to the round window.

5. The vibration of the basilar membrane causes the movement of hair cells.

6. Information about the location and intensity of stimulation is relayed to the brain through the cochlear nerve.

Sound and noise are measured in decibels and the scale is related to the range perceived by the human ear. The decibel system is based on a logarithmic scale, such that an increase of 3 dB requires twice the energy. So a sound level of 100 dB contains twice the energy of a sound level of 97 dB. This is called the Three Decibel Rule, which means that sounds at 88 dB are actually twice as intense as they are at 85 dB, and 115 dB is 1000 times as intense as 85 dB.
Are you beginning to understand why loud noise can injure our ears?

Distance also plays an important role in the perceived sound level. Sound levels decrease by approximately 6 dB every time the distance from the source is doubled. Or put another way, sound levels increase by approximately 6 dB every time the distance to the source is halved. Does this explain why your level of discomfort at a concert increases the closer you get to a speaker?

NOISE INDUCED HEARING LOSS

http://www.youtube.com/watch?v=L24ecL4ASXo

Noise Induced Hearing Loss – House Institute

Music is perceived as pleasant but sometimes is played loudly to produce its effect, witness Tchaikovsky’s 1812 Overture played outdoors with field cannon at the Starlight Symphony.

http://www.youtube.com/watch?v=BNatwyAJ6dI

Tchaikovsky’s 1812 Overture
Whereas the 1812 Overture is regarded as pleasant, the sound of a jet engine, is regarded as unpleasant. However, both are physically the same thing as far as the ear is concerned. If a sound level is too high or continues for too long, your hearing may be damaged.

The music and entertainment industries are unique in that high noise levels and extremely loud special effects are often regarded as essential elements of an event. High levels of sound are common, for example in orchestras, theatres and recording studios. Also those other studios for aspiring musicians ..........bars and nightclubs. Loud sounds, whatever their source, can damage hearing.

Hearing loss from noise exposure can sometimes be temporary – have you ever come in from a performance or a concert with your ears ringing and your ability to hear a little muffled? Most of the time that will go away within a few hours or a few days, but over time it does not go away, and you are left with permanent hearing loss.

Hearing damage is permanent, irreversible and ultimately causes deafness - hearing aids cannot reverse it. Even though noise-induced hearing loss is preventable...after it has occurred, it is a permanent and irreversible condition.

Performers and other workers in music and entertainment are just as likely to have their hearing permanently damaged as workers in other industries where loud noise is present – construction work, factory work, military, etc. And young musicians are just as likely to be afflicted with
noise induced hearing loss as older musicians.

Reducing noise risks in music and entertainment is not about destroying art, but about protecting people - artists, performers and ancillary workers. The hearing of all is critical and needs to be protected. There are cases of artists and performers being unable to carry on their profession because of hearing damage as a consequence of their work.

I have personally had two patients who had hearing loss and very bothersome distortion of sound with tinnitus or ringing in their ears that forced them to leave their chosen field as music directors. With proper education and planning, the risk from noise in the workplace and the risk of damage to musicians' hearing can be reduced.

Today I hope to provide some practical advice on how to prevent or at least minimize the risk of hearing damage from the performance of or listening to both live and recorded music.

A recent study addressed aging and noise as the most common causes of hearing loss in developed countries. Findings suggested that occupational noise-induced hearing loss probably accounts for 5 to 10 percent of the hearing loss found in adults in the United States. Further, findings suggested that non-occupational noise exposure probably accounts for an additional 5 to 10 percent.
Noise-induced hearing loss was identified as the most preventable form of hearing loss.

The number of people developing noise-induced hearing loss which can be directly attributable to occupational noise exposure appears to be decreasing, while the risk of noise-induced hearing loss from recreational noise exposure (firearms, concerts, movies, video games, computer games, personal sound systems…) appears to be on the rise.

The noise exposure level, or noise dose, takes into account both the level of exposure to noise, and how long the noise lasts. Generally speaking, the potential for hearing damage from noise is related to the noise 'dose' a person receives. Being exposed to a noise level of 105 dB (perhaps a bar band) for 5 minutes would be the same dose as being exposed to 94 dB (a nightclub bar) for 1 hour, or 88 dB (chamber music) for 4 hours.

Conversely, halving the noise dose can be achieved either by halving the exposure time, or by halving the noise level, which corresponds to a reduction of 3 dB. These noise exposures are identical:

- 80 dB for 8 hours
- 83 dB for 4 hours
• 86 dB for 2 hours
• 89 dB for 1 hour
• 92 dB for 30 minutes

The Equal Energy Principle states similar damage to the cochlea will occur from loud sounds of a short duration as to softer sounds of a longer duration. Noise or sound is harmful to human ears when exposed to 85 dB(A) for eight hours and increasing noise intensity by 3 dB doubles the energy output. Therefore, exposure time must be reduced by half, for every additional 3 dB of sound to maintain (relatively) safe noise exposure levels.

Each 3 dB added doubles the sound energy. When 10 dB is added, the energy is increased ten times, while adding 20 dB is a hundred times increase.

Individual variability plays an important role in noise-induced hearing loss. When individuals are exposed to identical noises, some may develop noise-induced hearing loss while others may not. These results indicate that noise-induced hearing loss is complex and involves genetic, medical, and environmental factors.

It is important that people not forget their noise exposure when not at work because cumulative exposure leads to hearing damage, whether or not it is work-related. Sound exposure includes all the sounds heard during each day. Common off-hours exposure to high noise levels may
include audio and video equipment, personal car stereos, computer speakers, televisions, concerts, clubs, movies, sporting events, power tools and noisy hobbies.

SYMPTOMS OF HEARING DAMAGE

Hearing loss can be temporary or permanent. People often experience temporary deafness after leaving a noisy place such as a nightclub or a rock concert. Although hearing recovers within a few hours, this should not be ignored. It is a sign that if you continue to be exposed to high levels of noise your hearing could be permanently damaged.

Permanent hearing damage can be caused immediately by sudden, extremely loud, explosive noises such as caused by fireworks. Remember that the hearing of young people can be damaged as easily as the old.

Hearing loss is usually gradual because of prolonged exposure to noise. It may only be when damage caused by noise over years combines with hearing loss due to
other causes that people realize how deaf they have become. This may mean their family complains about the television being too loud..... they cannot keep up with conversations in a group.......or they have trouble using a telephone. Eventually everything becomes muffled and people find it difficult to catch sounds like 't', 'd', and 's', so they confuse similar words. Musicians may suffer loss of discrimination between tones.

Hearing loss may not be the only problem. People may develop tinnitus, which is ringing or roaring in the ears, a distressing condition that can lead to disturbed sleep. Other more rare conditions include hyperacusis (a general intolerance of everyday sounds) and diplacusis (a difference in the perception of sound by the ears, either in frequency or time). Some research among symphony orchestras suggests more than 27% of musicians suffer hearing loss, with 24% suffering from tinnitus, 25% from hyperacusis, 12% from distortion and 5% from diplacusis. However, there are other studies that give a range of figures from 10-60% for hearing loss among musicians.

http://www.hse.gov.uk/noise/video/hearingvideo.htm

Video hearing loss
MYTHS

1. It's a free country. I don’t have to wear hearing protection if I don’t want to

Right on, and you are free to drive your car over the nearest cliff, or to jump of the highest bridge if you want to.

2. I’ll only be in this area for a minute or two

Everyone should wear hearing protection before entering an area with loud sound – everyone.

3. Foam earplugs are useless

Properly worn, all earplugs have their place in protecting people’s hearing,

4. I can’t hear people speaking to me when I’m wearing earmuffs or earplugs

There are flat response devices so that you can still hear all frequencies

5. Wearing hearing protection has given me ear infections

The wearing of earplugs or earmuffs is unlikely to be the cause of ear infections if you observe good hygiene.

6. If I have hearing tests or admit to hearing loss I’ll lose my job

As a musician it is in your best interest to view hearing tests as a positive way of pinpointing any hearing loss at an early stage, and seeing how well any actions to control noise risks are working.
Hearing tests will not prevent damage to hearing but regular tests will identify early signs of hearing loss and highlight the need for action to be taken to reduce the risk of any further damage.

7. Orchestras regularly play at 90-95 dB - so we won’t have the 1812 Overture to kick around anymore.

Louder pieces may be played less often. Musicians may need more recovery time. Attention should be given to the venues, orchestra layout, and elevating the brass so that they can be heard without having to play through five rows of fellow musicians.

8. Surely there’s no evidence of damage to hearing in orchestras

Wrong again – recall the study I mentioned earlier.

9. Hearing aids can restore hearing

Hearing aids can be a great help to many deaf or hard of hearing people, but they are no substitute for normal hearing.

10. All loud leisure noise is dangerous noise

One must consider the duration of exposure as well as the loudness of the noise exposure.

11. So audiences should wear ugly earmuffs or earplugs at concerts
Members of the public can and do buy their own earplugs.

12. If I like music, it is less damaging to my ears

Yes, and if I like ice cream, I won’t get fat by eating it. If your ears are regularly exposed to excessive noise you are at risk of hearing damage, whether you enjoy music or not. And relieving stress does not act as a mechanism to prevent hearing damage. Noise exposure is determined by the loudness of sound and its duration, period.

DO YOU HAVE A PROBLEM IN YOUR WORKPLACE?

You will probably need to do something about the noise if any of the following apply:

If the noise is intrusive – for example, as noisy as a busy road, a vacuum cleaner or a crowded restaurant – or worse than intrusive, for most of the working day;

If your employees have to raise their voices to carry out a normal conversation at least part of the day;

If your employees use noisy powered tools or machinery for more than half an hour each day;
If your field is one known to have noisy tasks, e.g. musicians or those who otherwise work in the musical arena.

FACTOID

In one study, approximately 44% of students reported using noisy equipment without ear protection. Male students were twice as likely to do so than female students. These findings are similar to other research findings that suggest that college men are more likely than college women to engage in risky activities. Are you really surprised at this?

SIGNS THAT YOU MAY HAVE A PROBLEM

1. When I am listening to my headphones, people next to me can hear my music. For reducing the volume of portable headsets, partial success has been reported with the use of warning signs posted near elevators and the request from a peer to reduce the volume.

http://www.youtube.com/watch?v=kLSYq5kau_w
2. When I go to concert I want to sit near a speaker – “sensation seeking” is a trait defined by listening to intense music to try and experience hearing loss and/or tinnitus following the listening experience.

3. I have had, in the past, ringing in my ears.

4. I have had, in the past, difficulty understanding speech after a noisy activity.

5. I really don’t think I’ll lose my hearing until I am older.

6. Although my ears ring after a social activity, the ringing goes away and I don’t think I have to worry.

7. I don’t believe that loud music can cause hearing loss.

8. Even if I lose my hearing, it can be “fixed” by hearing aids - students need to understand the limitations of hearing aids.

9. I don’t wear hearing protection during loud activities such as a concert, because I feel the music is more difficult to hear with hearing protection.

[One possible strategy for promoting use of hearing
protection devices may be to allow students to experience simulated hearing loss or tinnitus thus simulating an internal trigger.]

http://www.hse.gov.uk/noise/demonstration.htm

Audio hearing loss

Hearing protection falls into two broad categories: earplugs and earmuffs.

Many workers in music and entertainment, such as musicians, performers and sound engineers, need to hear sounds with as little distortion as possible, especially in the higher frequencies. This can cause problems as common hearing protection tend to reduce higher frequencies more than lower frequencies. For example, a compressible foam plug that reduces sounds in the 125 Hz range by 25 dB may reduce sounds in the 4000 Hz range by almost 40 dB.

Fortunately, specialized hearing protection is available that can reduce sound levels almost equally across a broad range of frequencies. This means that the user perceives the sound as being far more natural than with ordinary earplugs. These products are usually called ‘flat’ or ‘uniform’ attenuation hearing protectors. They come in both earplug and earmuff types.
Hearing Health Surveillance

A Suggestion for Musicians:

A baseline audiogram when starting, or within 3 months of starting work.

A re-test in 1 year to be sure the musician is not ‘hypersensitive’ to noise damage.

Consider further audiometric tests depending on the results of either test, or in the event of an adverse exposure to noise, e.g. a loud peak of sound through unlimited headphones.

The maximum interval between subsequent audiometry tests should not exceed 3 years in this situation.

Students may want to keep their own records of their estimated daily and weekly exposure.
TAKE HOME LESSONS FROM TODAY’S PRESENTATION

1. You are ultimately responsible for your own hearing health.
2. Remember the three elements necessary for hearing loss to occur – loudness, duration, and your presence.
3. Remember the three things you can do about loud sound – walk away from the noise, turn down the volume, and wear ear protection.
4. Remember the Three Decibel Rule – the sound energy doubles with every three dB increase.
5. If a sound hurts your ears, do something!

Fun

http://www.dangerousdecibels.org/virtualexhibit/index.html
<table>
<thead>
<tr>
<th>Source of sound</th>
<th>Sound pressure level</th>
</tr>
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<tbody>
<tr>
<td>Sound in air</td>
<td>dB re 20 μPa</td>
</tr>
<tr>
<td><strong>Stun grenades</strong></td>
<td>170–180 dB</td>
</tr>
<tr>
<td>.30-06 rifle being fired 1 m to shooter's side</td>
<td>171 dB (peak)</td>
</tr>
<tr>
<td><strong>Jet engine</strong> at 30 m</td>
<td>150 dB</td>
</tr>
<tr>
<td><strong>Threshold of pain</strong></td>
<td>130 dB</td>
</tr>
<tr>
<td><strong>Vuvuzela horn at 1 m</strong></td>
<td>120 dB(A)[7]</td>
</tr>
<tr>
<td><strong>Jet engine</strong> at 100 m</td>
<td>110 – 140 dB</td>
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<tr>
<td><strong>Non-electric chainsaw at 1 m</strong></td>
<td>110 dB[8]</td>
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<tr>
<td><strong>Jack hammer</strong> at 1 m</td>
<td>approx. 100 dB</td>
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<tr>
<td><strong>Traffic on a busy roadway at 10 m</strong></td>
<td>80 – 90 dB</td>
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<tr>
<td><strong>Hearing damage</strong> (over long-term exposure, need not be continuous)</td>
<td>85 dB[9]</td>
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<tr>
<td>Source</td>
<td>Decibel Level</td>
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<td>Passenger car at 10 m</td>
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<td>Handheld electric mixer</td>
<td>65 dB</td>
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<td>Normal conversation at 1 m</td>
<td>40 – 60 dB</td>
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<tr>
<td>Very calm room</td>
<td>20 – 30 dB</td>
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<td>Light leaf rustling, calm breathing</td>
<td>10 dB</td>
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<tr>
<td>Auditory threshold at 1 kHz</td>
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