Creating Science – Reversible Ears

Sound travels by waves, but what can those waves do? #CreatingScienceReversibleEars

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Physical sciences 1: Light and sound are produced by a range of sources and can be sensed.
- Physical sciences 8: Energy appears in different forms including movement (kinetic energy), heat, and potential energy, and causes change within systems.
- Physical sciences 9: Forms of energy can be transferred in a variety of ways through different mediums.

Science inquiry skills

- Communicating 5: Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)

Science as a human endeavour

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)

Cross curricular outcomes

Health and physical education

- Contributing to healthy and active communities 4: Discuss and interpret health information and messages in the media and internet (ACPPS039)

Science vocabulary words

Tier 1 (Everyday words) – noise, sound, ear, listen.

Tier 3 (Specialised vocabulary)

- Vibration – a wobble; forwards, and backwards that returns to the start.

Warning

- When you channel sounds into a funnel IT GETS MUCH LOUDER! Be careful, and warn students. The noise can hurt.
- Sticky tape and cutting implements are used, please be careful.

Preparation

- Some musical instruments for children to play with, at least one with variable pitch (such as a recorder). You may also like to acquire;
  - A percussion instrument such as a xylophone
  - A brass instrument such as a trombone.
  - A string instrument such as a violin.
  - A wind instrument such as a flute, or bottles with various amounts of liquid in them.
- Some thin, hollow plastic piping. About 1cm wide is ideal. You'll need two pieces, about 50 centimetres long.
- Loads of sticky tape.
- Two funnels, or a piece of cardboard rolled into a funnel (breakfast cereal boxes are fine).

Disposal

- Separate plastic tubes from cardboard funnels, and place both in the recycling bin.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students' questions can and should guide student learning, more material is presented for your convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is well suited to this age group. Children at this age can have difficulty with focus. Avoid tangents if you're attempting to make a key point.

Middle:

This can be a good activity for this age group if students are allowed to pursue their questions.

Teen:

Some teens will have trouble appreciating the complexity within this simple lesson. Try adding maths; there are many formulas online relating an object's properties to the notes it will create. Can they predict and create a device to make a perfect middle C?

Learning Intent (student friendly)

'We are learning to' (WALT) – make some reversible ears, and understand about sound.

Success criteria

'What I'm looking for' (WILF) – working reversible ears, and a clear discussion of sound waves.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as 'learn about hearing' or 'find a way to trick my ears'.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations? Such as build a science toy that has to do with sound, and explain its working.

Engage

Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

- ⇨ Play with some musical instruments and toys that make sound. See what questions students have about the objects and sound energy.

Explore

[Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!]

- ⇨ Focus students' attention with the observation that different instruments make higher and lower notes. See what explanations they can come up with for this observation.

Explain

Sound is made from waves, this we already know.

- Use a balloon to illustrate the waves of sound. When it is inflated and allowed to deflate you can literally see the waves made by the balloon from its nozzle. The waves in the air look a little similar.
- You can feel sound waves by touching a speaker that is playing music. In general, the louder and lower the note, the easier it is to feel.
- Test scientific thinking with a music box – how can we make the sound louder? We need to make the waves bigger, and a hard table will do this.

But did you know that only waves of a certain size will fit in a musical instrument, and that to make a different note (higher or lower) the instrument has to change?

- ⇨ Demonstrate this:
    - **Guitar** or **violin** strings must become shorter or longer (also tighter or looser) to have different notes. **Rulers** strung along the edge of a table make sounds depending on their length.
    - **Xylophone** bars or **resonance rods** are different lengths, producing different sized waves and thus differently pitched notes as the waves run along them.
    - Wind instruments such as **bottles with water in them** will depend on the size of the instrument to determine their size, and thus, pitch.
    - Brass instruments such as the **trombone** will change pitch depending on size. **Trumpets** use pistons to change the size of the waves.
    - A sea shell placed up to the ear filters out most sound waves except the ones that fit nicely inside the shell, thus a surreal wooshing sound results.

Pitch

The number of waves per second is the exact measure we use to determine the pitch of a sound. So a tuning fork with 440 beats per second literally vibrates backwards and forwards exactly (well, in an ideal situation) four hundred and forty times in one second[1].

- What pitches are too low, or too high, for humans to hear? (20 – 20,000 beats per second, and the difference gets smaller as you get older).
- Why do bats and dolphins use high pitched sounds in echolocation? (There are many good reasons, including that because more waves to help 'resolve' the image. Also, all waves curve around objects in their path, and high pitched waves curve the least.)
- Why do whales use low pitched sounds to communicate across the world? (They travel further. In some places, whales can make sounds that travel half way across the world!)

Directing sound waves

Waves travelling down tubes tend to lose much less energy than waves in the open, because the energy isn't spread out over a large space but contained within the tube (for the most part). We can use this property to help direct the sound to wherever we'd like it to go. Try the 'reversible ears' activity from online.

Harmonics

Did you know that you can always fit more than one wave in a musical instrument? The waves that are whole number fractions of the original note (i.e., ½, 1/3, ¼ etc.) make up the 'harmonics' of a musical instrument.

- Illustrate with brass instruments, which require a change in mouth tension to create the different notes when the instrument itself hasn't changed length.
- Illustrate with the spinning sound tubes. When you spin faster they make different noises because different sized waves are being formed. (The noise is created as the air rushes down

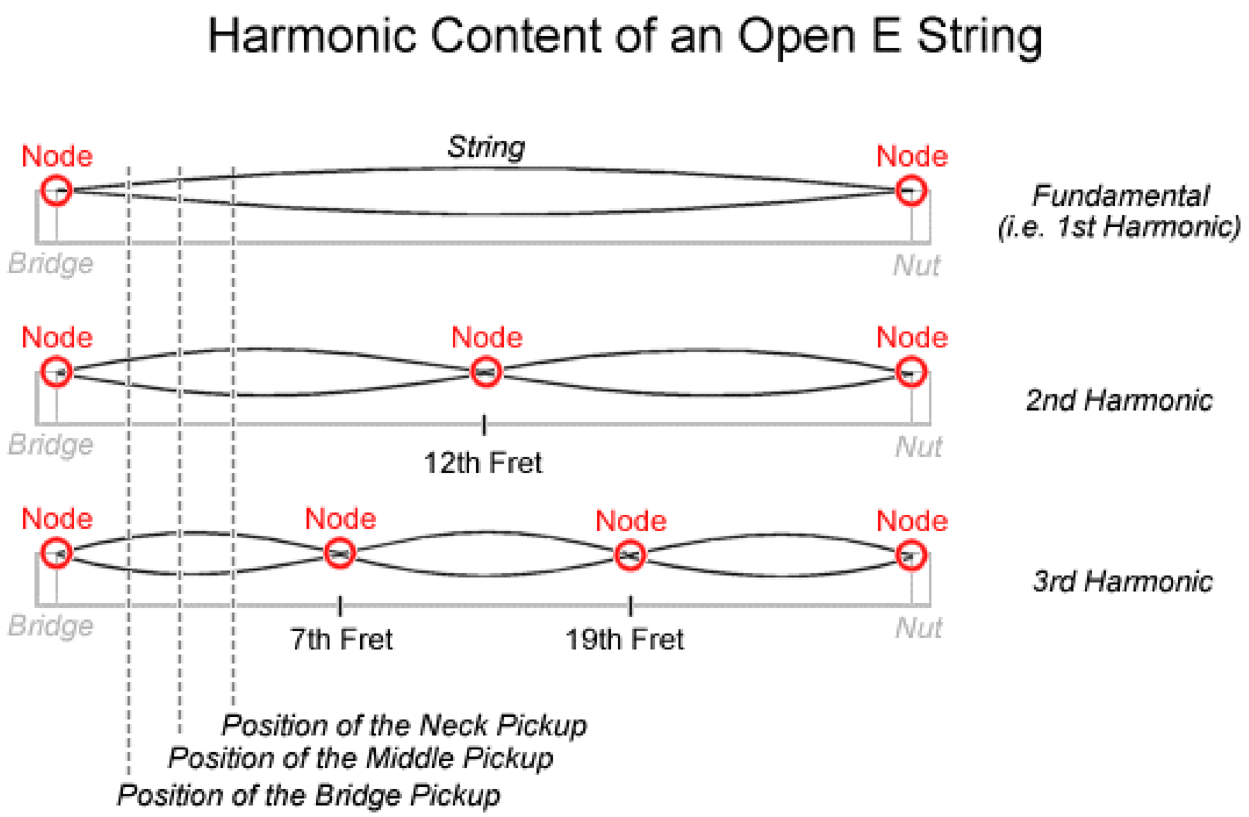
[1] Factors such as humidity and temperature of the room often affect the frequency ever so sleightly.

the tube, due to centripetal forces, and 'trips' on the bumps along the way, forming waves in the air).

- You can illustrate this simply with a slinky (or skipping rope) held between two people and swung gently so as to make a wave (known as a standing wave). Notice you can't make "one and a half" waves, you have to make one, or two, or three etc. (the parts where the waves are largest are called 'antinodes', and the parts where the slinky hardly appears to move at all are called 'nodes')

High school – harmonics

Check out this cool diagram (and loads of fun wave maths) at http://chubbyrevision.weebly.com/waves.html



Though the animation at 'harmonics and overtones' on Wikipedia https://en.wikipedia.org/wiki/Harmonic is also very cool.

Thus, every object has a main note it can easily make, a family of harmonics that it has no trouble calling on occasionally, and all the other potential notes are kind of left out!

⇨ Waves that don't quite fit, that are a little too big or too small, will quickly be overpowered by the waves that do fit nicely, and thus they tend to fall away leaving us to hear only those waves that fit.

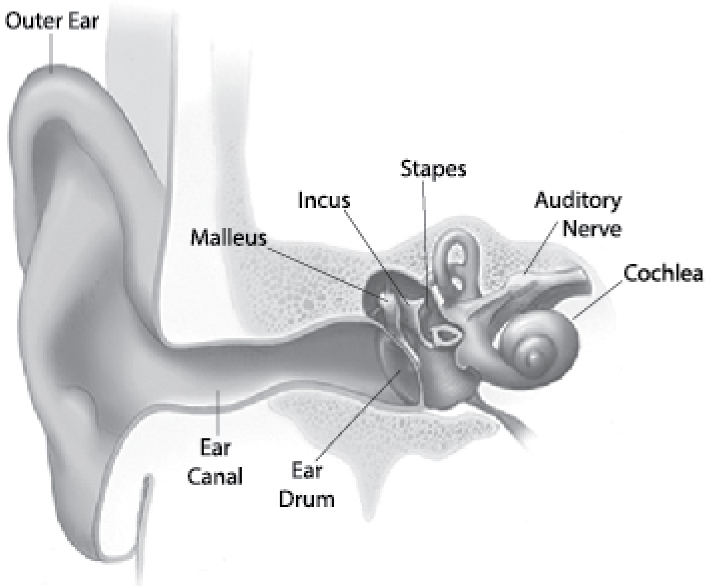
- Try listening to the world through a **shell or tube**. The size of the item will determine which pitches of sound tend to exist best in that area, and the others are filtered out just a little. This can made for some very strange sounds!

Elaborate

How Do We Hear?

Taken 26 Jan 21 from https://www.nidcd.nih.gov/health/how-do-we-hear#:~:text=Sound%20waves%20enter%20the%20outer,malleus%2C%20incus%2C%20and%20stapes.

Hearing depends on a series of complex steps that change sound waves in the air into electrical signals. Our auditory nerve then carries these signals to the brain. Also available: Journey of Sound to the Brain, an animated video. (*Source*: NIH Medical Arts)



1. Sound waves enter the outer ear and travel through a narrow passageway called the ear canal, which leads to the eardrum.
2. The eardrum vibrates from the incoming sound waves and sends these vibrations to three tiny bones in the middle ear. These bones are called the malleus, incus, and stapes.
3. The bones in the middle ear amplify, or increase, the sound vibrations and send them to the cochlea, a snail-shaped structure filled with fluid, in the inner ear. An elastic partition runs from the beginning to the end of the cochlea, splitting it into an upper and lower part. This partition is called the basilar membrane because it serves as the base, or ground floor, on which key hearing structures sit.
4. Once the vibrations cause the fluid inside the cochlea to ripple, a traveling wave forms along the basilar membrane. Hair cells—sensory cells sitting on top of the basilar membrane—ride the wave. Hair cells near the wide end of the snail-shaped cochlea detect higher-pitched sounds, such as an infant crying. Those closer to the center detect lower-pitched sounds, such as a large dog barking.
5. As the hair cells move up and down, microscopic hair-like projections (known as stereocilia) that perch on top of the hair cells bump against an overlying structure and bend. Bending causes pore-like channels, which are at the tips of the stereocilia, to open up. When that happens, chemicals rush into the cells, creating an electrical signal.
6. The auditory nerve carries this electrical signal to the brain, which turns it into a sound that we recognize and understand.

Can you trace the path of the sound waves down the inner ear as they are turned into electrical signals our brain can understand?

Harmonics

These harmonics (explained above) are actually what give every instrument its 'tone colour' – or the quality that makes one instrument distinguishable from another instrument.

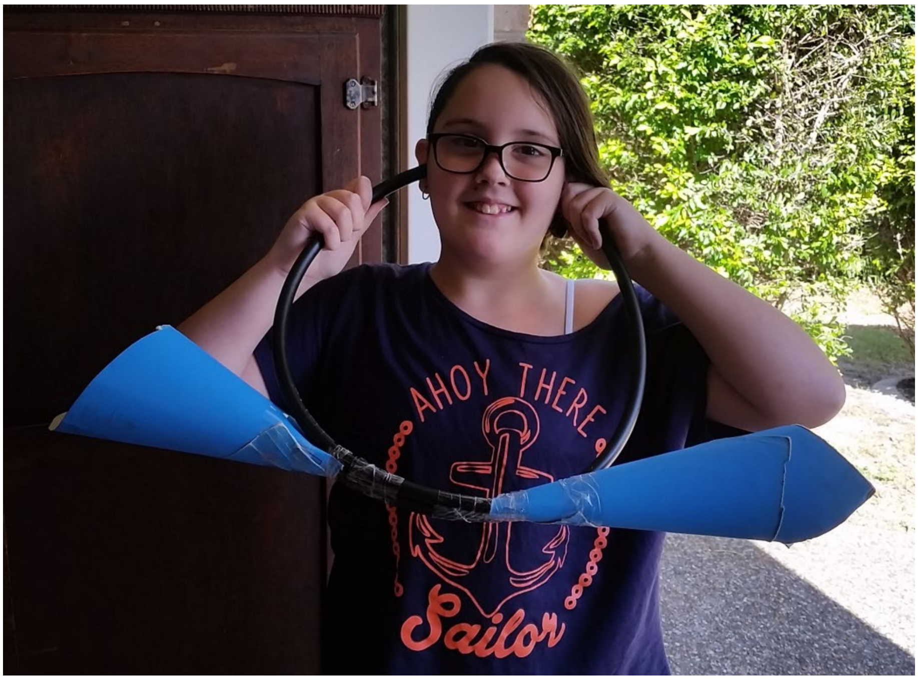
- One reason we cannot tell instruments apart when they are playing very high notes very well may be because we cannot hear the even higher harmonics that are being played.
- And yet, research indicates that without those inaudible harmonics, music feels artificial…

More advanced stuff

This is the beginning of wave mechanics, and it means sound can form harmonies, nodes and antinodes, constructive and deconstructive interference, refraction, and dissipation using the inverse square of the distance from the source. These rules work for everything that moves in waves, including;

- Light
- The tides
- Bridges in the wind
- Traffic
- People's shopping habits
- Etc., etc.

And believe you me, LOTS of things move in waves!!



Evaluate

⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- Did you achieve your learning goal?
- What did you learn?
- How can we represent the shape and movement of soundwaves more effectively?
- What further questions do you have after this study and experiment?

Assessment

Prior learning:

Take time to focus on planned content material during the engage phase. For example:

- Why do sounds sound different?
- Why are some sounds higher than others?

Formative:

Test learning as you go along, for example:

- Can you make a note the same pitch with different objects?
- Why can't the spinning tubes make a sliding scale? (the waves of the other notes don't 'fit')

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- Give an oral demonstration of their learning, using as many instruments as possible.
- Build an instrument that gives at least five notes, and tune them.

So what?

Sounds are made of invisible waves that can move around, in and through objects. We can control and direct those waves in many different ways.

Creating science

Science understanding

As students saw that sound is made up of waves, and only waves of a certain size will fit in any material object to create the pitch of a note (and the other, smaller, waves that fit combine to make the tone colour of the note), they could learnt that;

- Physical sciences 1: Light and sound are produced by a range of sources and can be sensed.
- Physical sciences 8: Energy appears in different forms including movement (kinetic energy), heat, and potential energy, and causes change within systems.
- Physical sciences 9: Forms of energy can be transferred in a variety of ways through different mediums.

Science inquiry skills

As students built models to help us explore science ideas, they might see that;

- Communicating 5: Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)

Science as a human endeavour

As students discovered that we don't know who discovered the science of waves, probably several people working independently. Even the ancient Greeks knew about it. It's very, very old science, and it still works!!

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)

Cross curricular outcomes

As students learnt about hearing, and tricked their ears with the Reversible Ears, they saw that;

Health and physical education

- Contributing to healthy and active communities 4: Discuss and interpret health information and messages in the media and internet (ACPPS039)

Fun facts about hearing: Human Edition

Taken 26 Jan 21 from https://www.signiausa.com/blog/fun-facts-about-hearing-1/

Listening to music, waking up to birds chirping — you get to enjoy those sounds and more because of how human ears function. Our ears are complex organs that allow us to hear all the beautiful things life has to offer. Although you might take hearing for granted, there are many things you probably don't know about the way it works.

Listening to music, waking up to birds chirping — you get to enjoy those sounds and more because of how human ears function. Our ears are complex organs that allow us to hear all the beautiful things life has to offer. Although you might take hearing for granted, there are many things you probably don't know about the way it works. Here are eight fun facts about human ears:

1. Your inner ears are responsible for both hearing and balance, so a disease that affects one system can also have an impact on the other. For example, Meniere's Disease is characterized by low frequency hearing loss and dizziness.

2. The cochlea, is the innermost part of the ear, and is about the size of a pea! It looks similar to a snail shell, and if unraveled would be a mini-tube about 31.5mm long.

3. The middle ear contains the smallest bones in your entire body, with the stapes being the tiniest. These three little bones help transmit sounds to the inner ear. All together, they can fit on a penny!

4. Humans can hear frequencies as low as 20 Hertz (Hz) and up to 20,000Hz.

5. While you're sleeping, your ears continue to function. They will pick up sounds, but your brain blocks them out.

6. Ears detect most sounds, but they have limits. When a sound exceeds a certain frequency level, it registers only as ringing or buzzing in our ears (not to be confused with tinnitus, which is a ringing, buzzing, or similar sound with no external cause).

7. Your ears are self-cleaning. Pores in your ear canal produce cerumen (aka, earwax), and tiny hairs called cilia push it, along with the detritus it traps, out of the ear canal naturally. Although many find earwax "gross", it protects the ear from dust, dirt, and friction, and unless you produce an excessive amount, doesn't require cleaning out.

8. The sensory neurons responsible for hearing are called hair cells. They are found inside your cochlea in the inner ear. If enough of these cells are damaged or destroyed by the aging process, excessive noise exposure, ototoxic substances, or lack of adequate blood supply, the result is hearing loss. Unfortunately, most hearing loss is irreversible because those hair cells do not grow back.

While human ears are fascinating, animal and insect hearing can be even more impressive. We'll have more about that in part two of this post, Fun Facts About Hearing: Animal and Insect Edition. In the meantime, if you are concerned that your hearing isn't what it used to be, contact a hearing care professional to have it assessed and treated.

Fun Facts About Hearing: Animal and Insect Edition

Taken 26 Jan 21 from https://www.signiausa.com/blog/fun-facts-hearing-animal-insect-edition/

While the way human ears work is fascinating, … animal and insect ears and hearing abilities can be even more impressive. Here are some interesting facts about their hearing.

1. Because of bats' terrible night vision, they've gained the ability to navigate using echolocation, which utilizes sound waves and echoes to identify objects in their path. Bats release a series of squeaks and sounds that bounce back to the bat's ear in order for them to perceive what's around them in relation to distance or prey. Dolphins also navigate the seas via echolocation.
2. Elephants' large, thin ears don't just enable them to hear; they also help the pachyderms regulate their internal body temperature.
3. The greater wax moth takes the crown for hearing high frequencies — up to 300 kilohertz (kHz). That's the ability to hear 150 times more than us, and 100 kHz above a bat. Being the main prey for bats, at least these moths have one advantage!
4. Cats have 32 muscles in each of their outer ears. For reference, humans have six. Those muscles give them the ability to rotate their ears so they can pinpoint the source of a noise. With hearing up 64 kHz, there's no use trying to sneak up on your cat.
5. Dogs have hearing abilities similar to cats, can hear higher pitches, and can even recognize different sounds. So, even if you're out of sight and walking into a room, your dog might recognize your footsteps and already know you're coming.
6. Pigeons have the ability to hear frequencies as low as 0.5 hertz (Hz), allowing them to hear sounds that are far away like storms, and also helps them navigate long distances.
7. Hearing up to 33 kHz, horses use their ears to communicate their moods — forward indicates alertness, pulled back communicates irritation, and somewhat sideways, relaxed ears show contentment. They have the ability to rotate each ear 180 degrees so they can determine where sounds are coming from in order to flee in case of danger.
8. Although their range of hearing isn't that different from a human's, an owl has a more acute sense of hearing that allows them to hear even the slightest movement of their prey. They also have asymmetrical ears — one ear is higher than the other (depending on the type of owl), which enables them to hear the same sound at two slightly different intervals.

Keep your ears functioning at their best!

Ears are capable of so much more than just hearing. In humans and animals alike, they serve multiple purposes, including helping maintain spatial awareness and balance. It's never a bad idea to learn more about your hearing and ways to keep it functioning at peak performance. Find a hearing care professional near you to keep up with your hearing health.

Reversible Ear – *Think and do* worksheet

Basic Science

Q: What 'shape' is sound?

A:

Q: How do we make sounds LOUD and SOFT?

A:

Q: How do we make sounds high pitched and low pitched?

A:

Extra challenge

Q: How can you make a note the same pitch with different objects?

A:

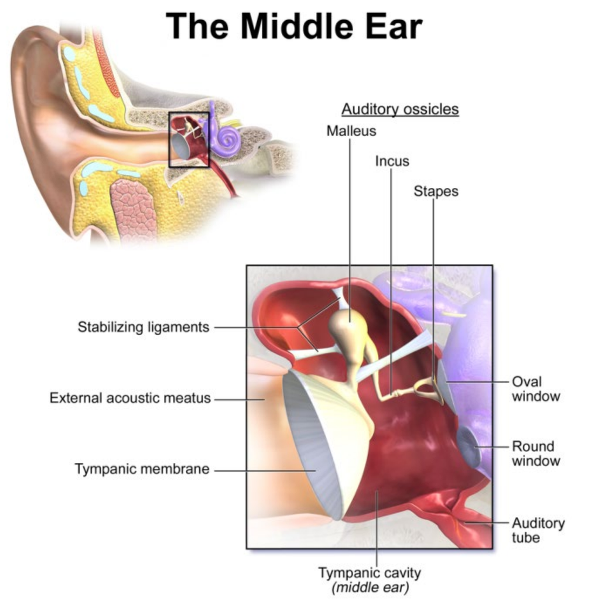
Advanced Challenges

Can you build an instrument that gives at least five notes, and tune them?

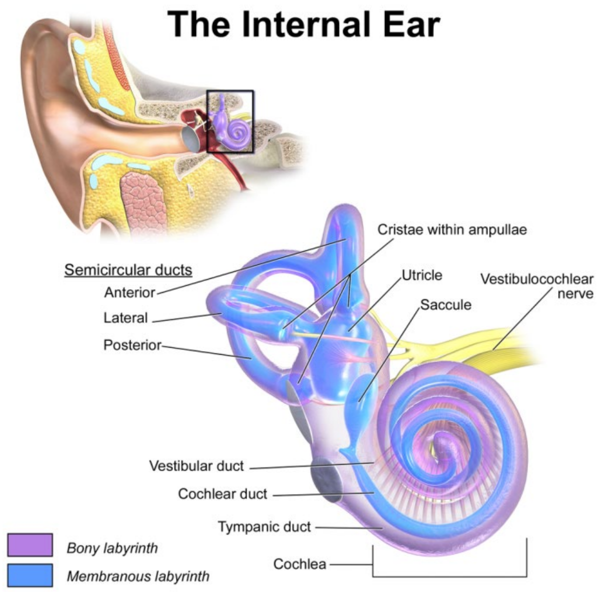
Why can't the spinning tubes, or any musical instrument of a fixed size, make a sliding scale?

Harmonics are what give each instrument their particular 'tone colour'. What are harmonics and what can they do for us?

Do you know the names and jobs of the different parts of your ear?



Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". *WikiJournal of Medicine* **1** (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436. - Own work

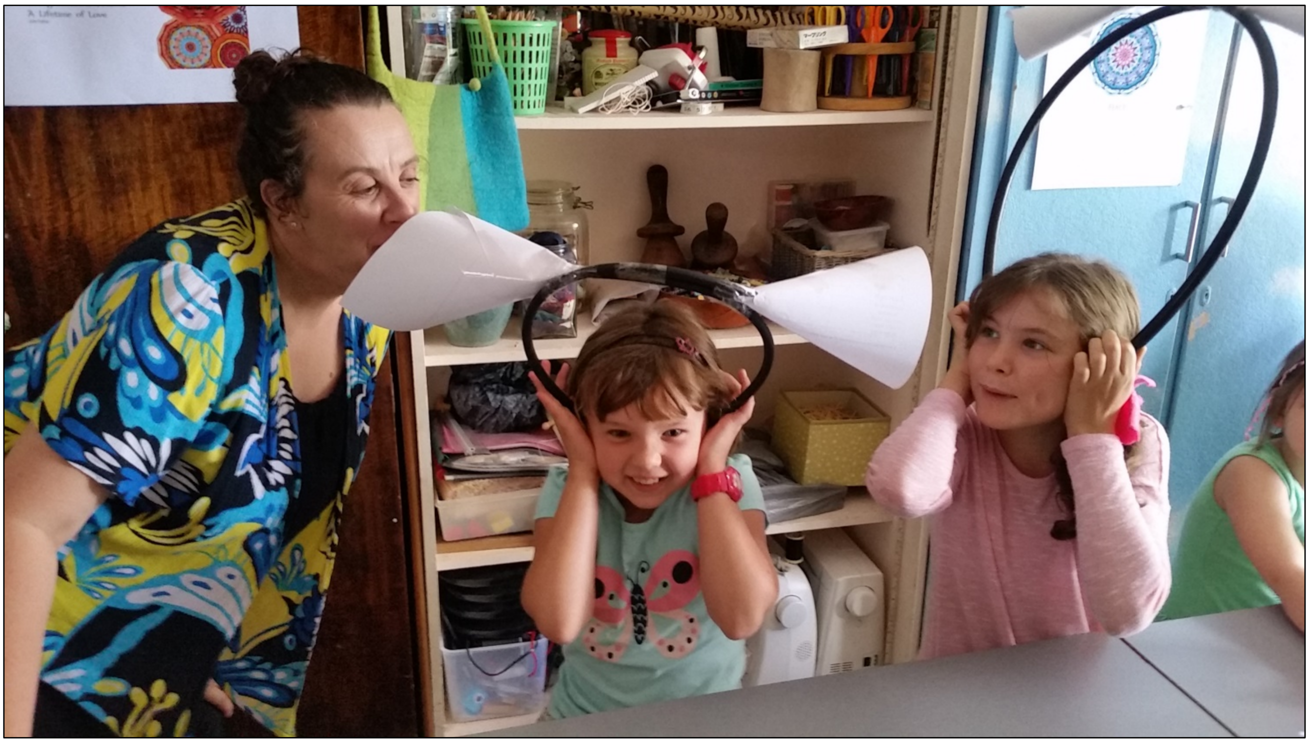


Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". *WikiJournal of Medicine* **1** (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436. - Own work

Tips from the Masters

Simple science is often the best!

Cardboard cones work just as well – grownup help is helpful!



Sound is wonderful!

DON'T SHOUT!!! IT CAN REALLY HURT!!