Listen and see

English texts of the exhibition

MUSÉE
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DES SCIENCES
GENÈVE

Listen and see *is an original and bilingual (french/english) exhibition of the Musée d’histoire des sciences of Geneva, presented from the 12th of May 2021 until the 27th of February 2022.*

More information about the exhibition on the website
www.ville-ge.ch/museum

Texts : Laurence-Isaline Stahl Gretsch and Stéphane Fischer
English translation : Liz Hopkins
Photos: Gilles Hernot, Drawings : Florence Marteau

Listen and see

Listen! do you hear it? shhhh!
Sounds surround us, they are part of our daily lives. But what exactly is a sound and, more importantly, what is sound?
At our exhibition you will find out all about this branch of physics and the wonderful world of sound waves.
En route!

Emblematic instruments of experimental acoustics from the 19th century

The Museum has some remarkable instruments from the 19th century, the golden age of experimental acoustics, in its collections. Some of them make sound vibrations visible, while others measure the pitch of sounds or analyse the timbre of the human voice or of musical instruments. They set the theme of our new exhibition Listen and see.

A brief history of acoustics

The birth of acoustics is sometimes attributed to Pythagorus and his disciples who, by inventing the monochord, would have observed that there is a link between the length of a vibrating string and the frequency of the sound produced. A few centuries later, Galileo, Mersenne and other scholars returned to Pythagorus’ work on the monochord and asked themselves questions about the nature of vibrations and the way in which they travel in the surrounding air.

Until the 19th century, acoustics remained an essentially empirical and marginal discipline. Using metal parabolas, it was observed that sound propagates and reflects like light. Acoustic horns to amplify sounds were made. Thanks to the first pumps, it was realised that sound needs a material medium to propagate itself.

The study of acoustics became more theoretical in the 19th century. Mathematicians developed formulae that described the form and movement of vibrating chords and measured the speed of propagation in a given medium. The theoretical work was verified by fieldwork. Canons fired during the night allowed researchers to gather precise measurements of the speed of sound in the air. The Geneva scholar Jean-Daniel Colladon was able

to experimentally demonstrate, on Lake Léman, that sounds propagate four times faster in water than in air, that is, at 1437 m/s.

During the 19th century, experimental acoustics became an independent branch of physics. Responding to the theoretical studies of physicians and physiologists such as Ernst Chladni (1756-1827), Charles Wheatstone (1802-1875), Heinrich Helmholtz (1821- 1894) and others, new instruments were developed which enabled visual observation of sound vibrations and sound waves as well as analysis of complex sounds.
By the 20th century those instruments, essentially mechanical and electromechanical, were being gradually abandoned in favour of new equipment – discharge tubes, oscilloscopes, sonographs, frequency generators – all based on a new technology: electronics.

Sound is a wave

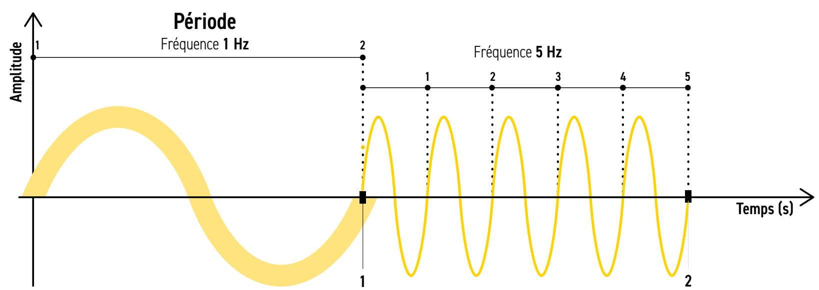
There are three main families of sound: mechanical waves, electromagnetic waves and gravitational waves.
Sound is a mechanical wave. Unlike the other two types of sound waves, mechanical waves need a medium through which to spread (air, water, solid material). The speed of propagation is highly dependent on the medium traversed (in addition to the temperature and pressure of the surrounding environment).

> ***Speed of sound*** *(at 15°C at sea level):*
>
> *- in air: 340m/s*
> *- in water: 148m/s*
> *- in a vacuum (space): 0m/s. Sound does not travel in a vacuum!*

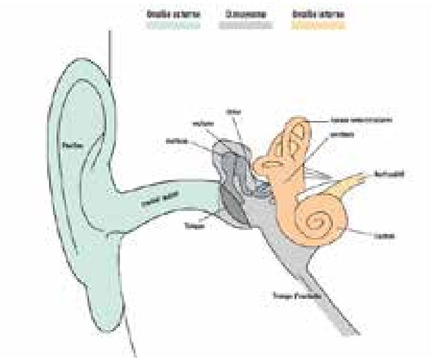
It is the movement which spreads, not the material itself. This can be seen in the example of a cork floating on a calm water surface. If a stone is thrown in, circular ripples form and move out from the point of impact. The cork bobs a little during the passage of the ripples (that is, the disturbance) but does not change position.

Sound can be described through various parameters:

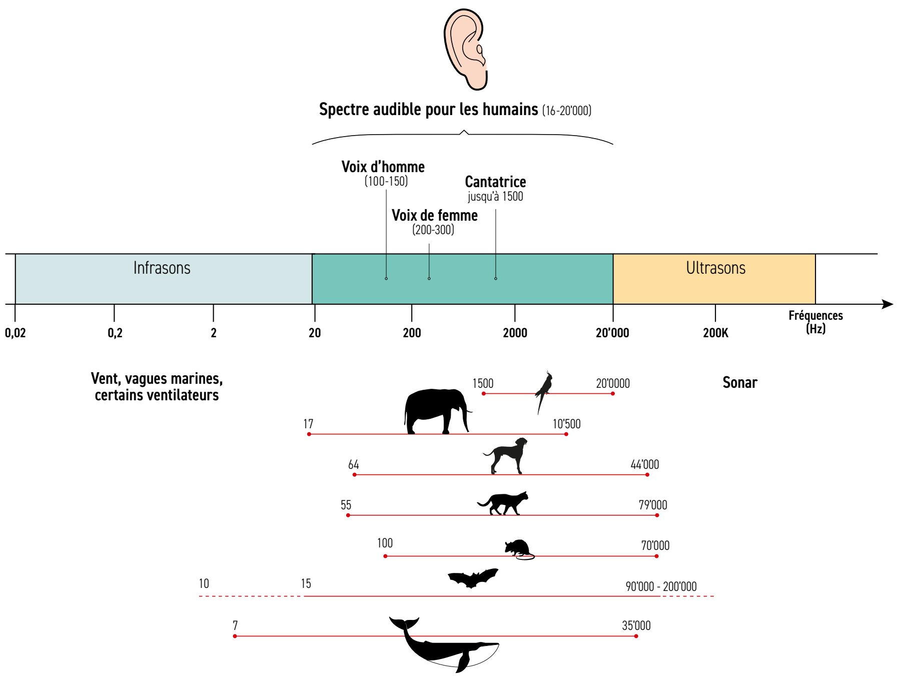
- frequency: the waves are shown as sinusoidal. Frequency is determined by the number of summits and hollows in 1 second. 1 cycle/second = 1 Hertz (Hz).
- period: that is, the length of a cycle. It is measured in seconds.
frequency is the inverse of the period and vice versa.
- wavelength: the distance travelled during one period measured in metres (m).
- intensity: the volume of sound which is proportional to the square of the pressure exercised on the environment, measured in Watt/cm^2. The values obtained are transformed into a logarithm then represented linearly in bels or decibels (db) which indicate the intensity relationship between two sounds. Intensity is independent of frequency.



Ears to hear with



Sounds call upon our sense of hearing.
The organ which enables us to hear is the ear. It is composed of 3 parts:
- The outer ear is formed of the pinna and the external ear canal which collects and amplifies sounds.
- The middle ear is composed of the tympanum (a membrane which vibrates like the skin of a drum), the three smallest bones in our bodies - the hammer, anvil and stirrup - and the eustachian tube (which joins the system to the throat and equalises the pressure over the tympanum). The middle ear converts air vibrations into physical vibrations.
- The inner ear consists of the vestibule (which plays a role in balance), the semi-circular canals and the cochlea (filled with liquid and lined with hair cells which vibrate more or less rapidly according to the frequency (low or high) of the sounds transmitted). Its function is to translate a mechanical signal into a nerve signal (transduction) which is then transmitted to the brain by the auditory nerve.

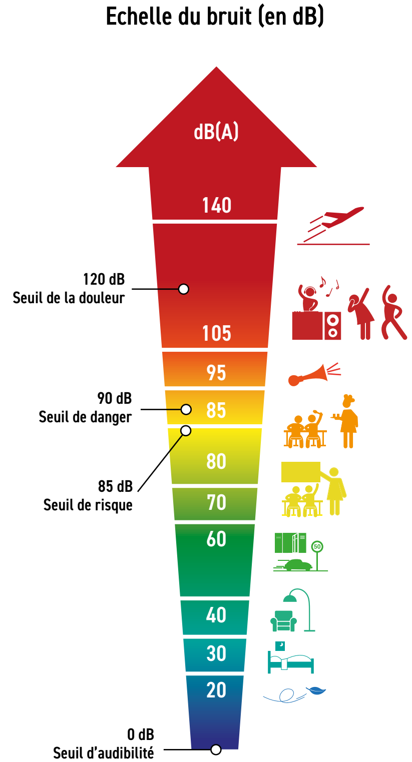


The audible spectrum

The spectrum of sounds is divided between the audible (what the human ear can hear), infrasound and ultrasound.

Too loud!

The threshold above which sounds become painful for humans is set at over 120 db (high pressure on the ear drum), but our inner ear already protects itself at around 80 db through muscular contraction of the middle ear associated with the three tiny bones (the stapedial reflex).



Creating a sound

Several factors contribute to the construction of a sound: a source of energy (breath, fingers on a chord, etc.), a vibrator (e.g., the chord of a guitar) and a resonator (the body of a guitar).
The human voice functions in this way with breaths (the lungs), a resonator (the larynx) and a tube (the vocal tract) whose height is adjustable thanks to the action of specialised muscles covered in mucous, the familiar vocal cords. When taut, they produce high sounds, when relaxed, the sounds are low.

Producing a tone: tuning forks

A tuning fork is a mechanical instrument (a piece of metal in the form of a Y) which produces a pure tone when vibrated. Tuning forks, which vibrate at 440Hz (that is the branches oscillate 440 times per second), give the reference tone A for orchestras.

A tuning fork must be used with a resonator to amplify its tone.

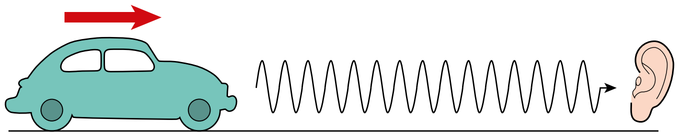
Mixing sounds

Sounds can be combined by superimposing waves and frequencies. This results in complex sounds.
Complex sounds can be broken down into a fundamental frequency which gives the height of the sound, that is, the tone (e.g. the famous A 440), and into several other frequencies which are multiples of the fundamental frequency. These define the harmonics which in turn determine the timbre of the tone. The timbre is what enables us to hear the difference between a flute and a guitar playing the same musical note.
A random mixture of sounds, aperiodic and of an unidentifiable height, is called noise.

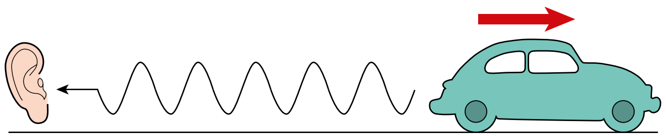
Some phenomena related to sound

The Doppler effect

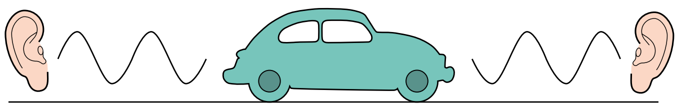
All of us have experienced the Doppler effect, even if we did not know it! This is what we experience when we hear a vehicle travelling fast. The sound of the motor is higher when the vehicle is approaching than when it is moving away.
This phenomenon occurs because the interval between successive waves of sound emitted by an object in movement is smaller in front of the object than behind it for a stationary observer. If the object does not move, the



Le véhicule se rapproche: le son est perçu plus aigu

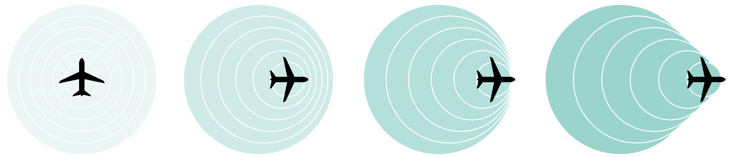


Le véhicule s'éloigne: le son est perçu plus grave



Le véhicule est immobile: le son reste inchangé

Ondes sonores émises par un avion



sound remains the same.

Wall of sound

A wall of sound is not made of bricks!
This term describes the aerodynamic phenomenon which occurs when a plane reaches or goes passed the speed limit of sound in air (340 m/s, or 1224 km/h). At that speed, the sound waves generated by the plane cannot be distanced from it and thus must accompany it. The waves in front of the plane are so compressed that they build up to form a shock wave, a kind of turbulent air barrier called a wall of sound. It is this shockwave which causes the supersonic boom heard on the ground when a plane flies at a speed equal to or above the speed of sound. As the shockwave travels more slowly than the plane, we hear the boom after the aircraft has passed overhead.

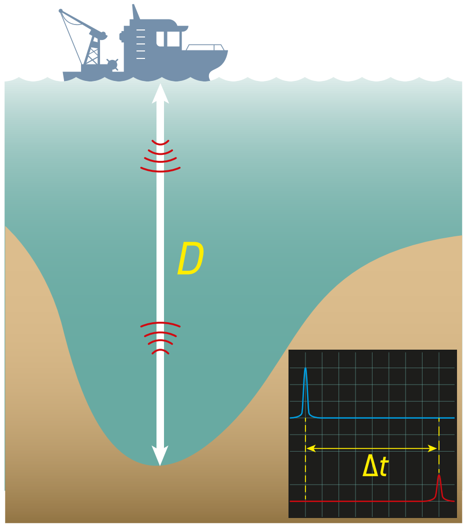
Seeing through sound

The mechanical properties of sound can be used to see. Bats especially use ultrasound but it is also used in submarines and by doctors using medical imaging. But infrasound too can reveal what lies underground for example.

The sonar system of bats

One of the animal world's most sophisticated sonar systems is that of bats. Bats send out a series of very short sounds from their mouths, usually at frequencies inaudible to the human ear. They then listen to and analyse the echoes reflected from obstacles. Thanks to this echolocation system, bats are able to detect the smallest objects such as a mosquito, a maybug or a tree leaf, almost in real time, in total darkness and at full speed! They literally "see" with their ears!
Chauve souris dans vitrine

The many uses of ultrasound



From 1915, warships were equipped with sonars (an English acronym of sound navigation and ranging) to detect the presence of enemy submarines. Like bats, the idea was to emit ultrasounds in water and analyse the echoes. Since then, sonars have also been used to determine water depth or localise swarms of fish.

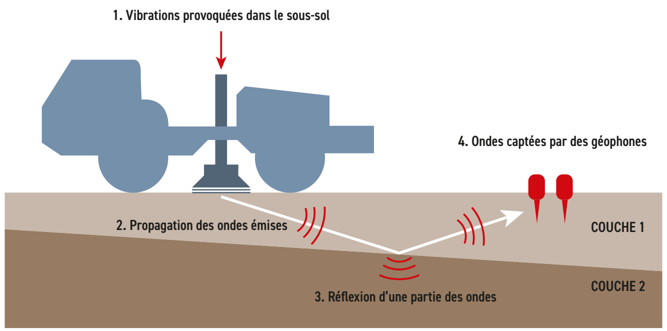
Ultrasound is used to explore the human body. Echography is now one of the most common medical imaging techniques in the context of prenatal diagnostics or the analysis of organs.

There are numerous applications of ultrasound for non-destructive assessment of various materials (tree trunks, beams, steel bars, industrial products, etc.). Analysis of the sound signals emitted and reflected in the materials enables the detection of possible internal faults (fissures, breaks, splitting, etc.) invisible to the naked eye.

An infrasound truck

Although more difficult to handle and use, infrasound is an excellent indicator, not only of natural phenomena such as earthquakes or high-altitude winds near mountains, but also of artificial events such as nuclear explosions, the boom of supersonic aircraft breaking the sound barrier, etc.

Closer to us and for a precise purpose, the utilities company of Geneva (Services Industriels de Genève) uses sound waves similar to infrasound in geophysical surveys of potential geothermal energy sites (Fig. 2.3). Specially equipped vibrator trucks place a slab on the ground which is made to vibrate for 20 seconds at a frequency of between 8 and 120 Hz. The waves reflected from underground are captured at the surface. The data are then treated electronically to reveal the geological profile up to 4000 m below the surface. Geologists can then map out the areas with the highest probability of hot water reserves to drill.



Sound pollution and noise

Nowadays, acoustics examines an issue which was not taken into consideration in previous centuries: sound pollution. City dwellers are confronted with many and incessant sources of sound of all kinds – air, road and rail traffic, industrial activities, neighbours – which cause stress, illness and social conflict.