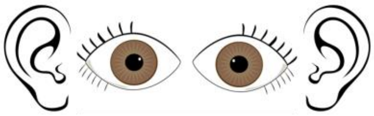
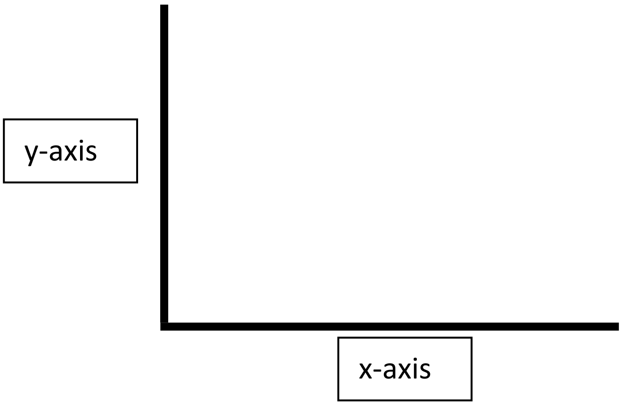
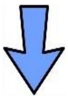
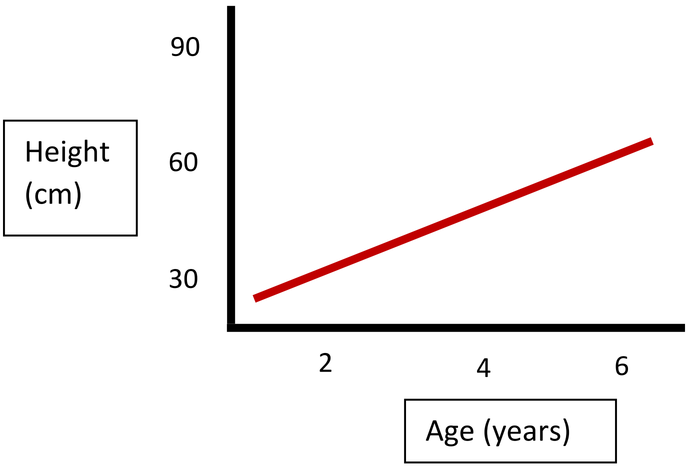


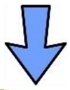
Looking at sound

Scientists don't just listen  to the sounds that they study, they also look  at those sounds. One way that scientists can look at sounds is by making a *spectrogram*. A spectrogram is a special kind of *graph*. A graph is a way to show data as a picture. It has an *x-axis along the bottom* and a *y-axis along the side*.

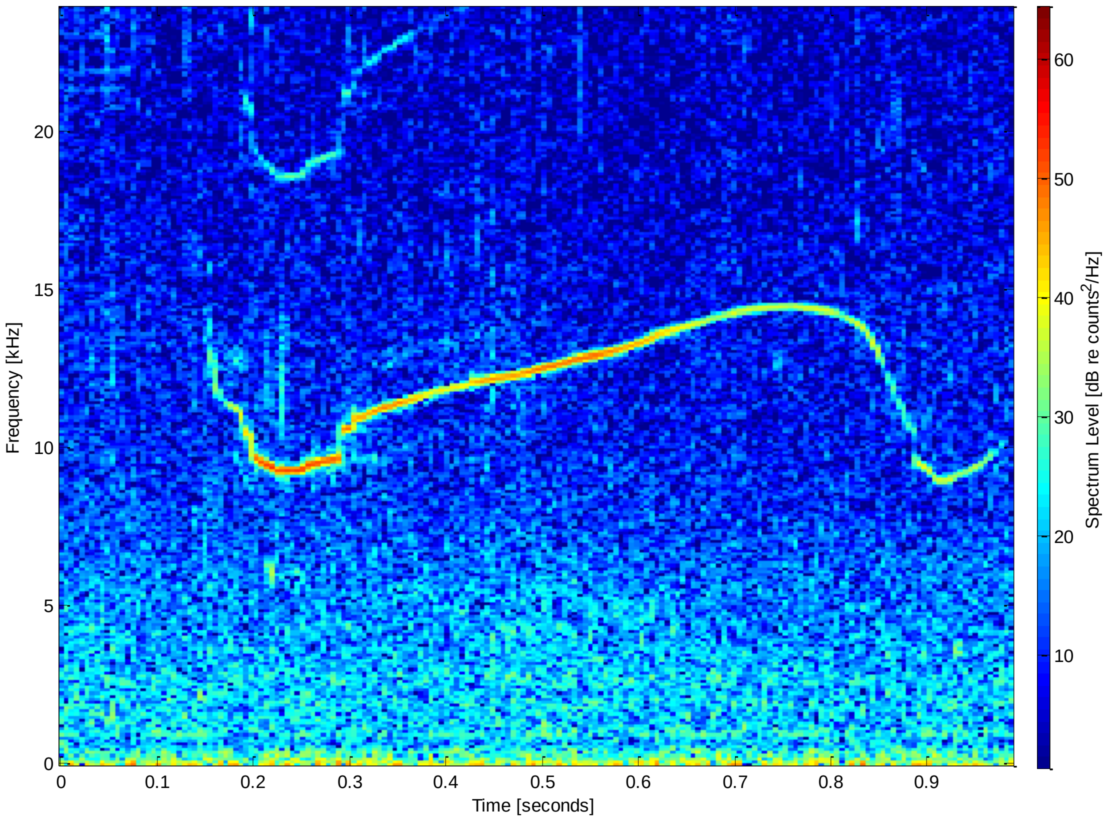


This  is an *example* of a graph. In this graph, *age*  is on the *x-axis* and is measured in *years* and *height*  is on the *y-axis* and is measured in *centimetres (cm)*. *This graph shows* that as someone gets *older*, they get *taller*.

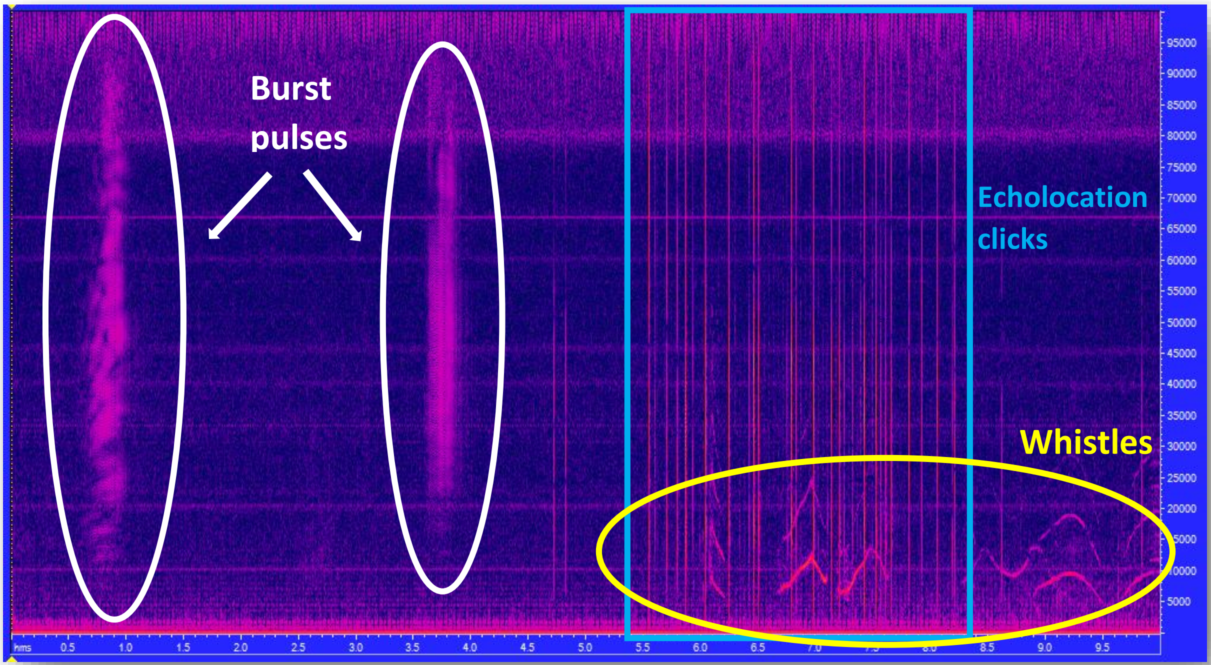


A spectrogram is a special kind of graph where *time*  is on the x-axis, *frequency*, or pitch, 's on the y-axis and the *intensity*, or loudness,  of the sound is shown in different *colours*. In the spectrogram below,  the ***quietest*** sounds  are shown in ***dark blue*** and the ***loudest*** sounds  are shown in ***red***.

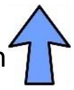
Frequency is shown on the y-axis in a measurement called *kilohertz (kHz)*. Sounds that are low-pitched, or deep like a bass guitar  or the low notes on a piano, are ***low frequency*** sounds and sounds that are high-pitched, like a flute  or the high notes on a piano, are ***high frequency*** sounds. The wavy red and yellow line in the middle of the spectrogram is a *dolphin whistle*. 



Different sounds **look**  different on spectrograms. Here is a spectrogram that shows different sounds  that are made by **dolphins**: 



One of the reasons that this spectrogram **looks different** than the first one we looked at is that this spectrogram was made using a different **computer program**  than the first one. It also uses a different **colour scheme**  to represent loudness. The highest frequency on the first spectrogram is **20kHz** and the highest frequency on the second spectrogram is **10kHz**.

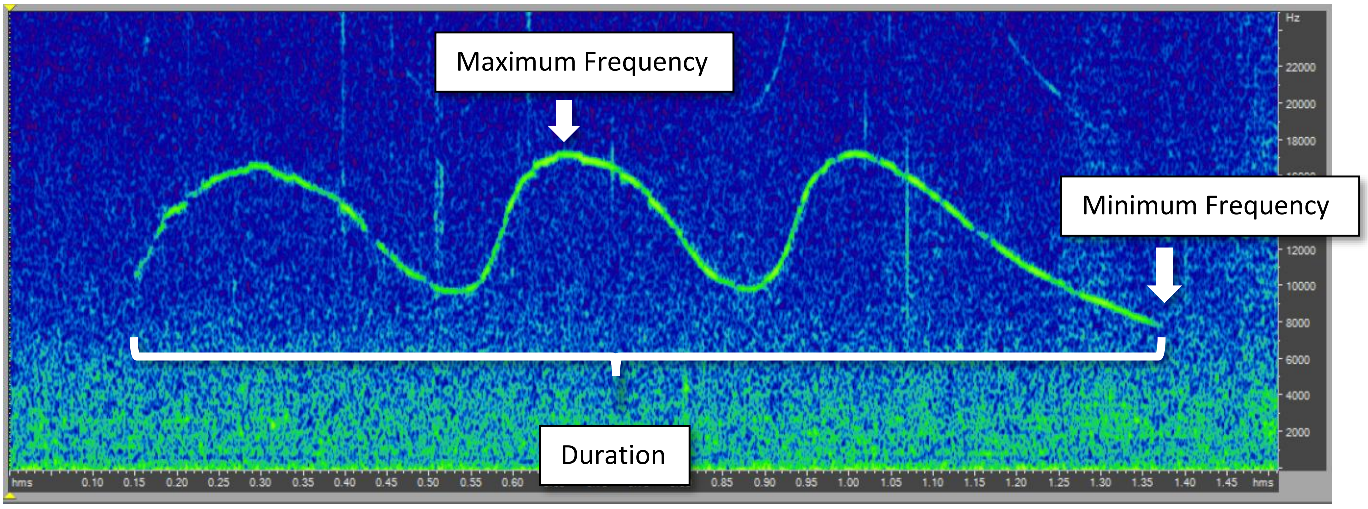
There are many different **computer programs**  that you can use to make spectrograms. Some of them are listed at the end of this worksheet. On this spectrogram  the **quietest** sounds  are **black** and the **loudest** sounds  are **bright pink**. Time  is shown in **seconds** on the x-axis and frequency  is shown in **Hertz (Hz)** on the y-axis.

Whistles (circled in yellow on the spectrogram) are long, wiggly lines. These sounds are used for *communication* – to talk to each other. They sound a lot like *bird* whistles.

Echolocation Clicks (surrounded by a blue box on the spectrogram) are very *short lines* that are straight *up and down*. These sounds are used for *echolocation*, or *sonar*. In other words, these sounds *bounce* off of the things around them, creating *echoes*. Dolphins *listen* to these echoes and that way they can *hear* what is nearby. **Bats** do this too! Echolocation clicks sound like someone *clapping their hands*.

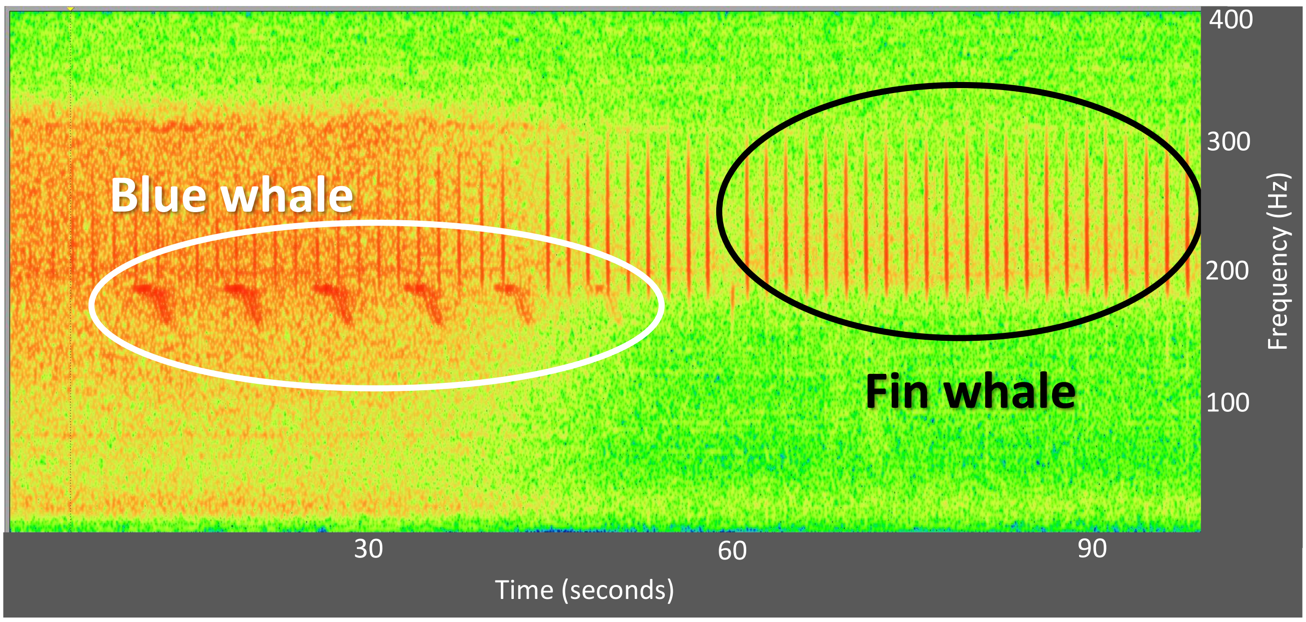
Burst pulses (circled in white on the spectrogram) are clicks that are *so close together* that we can't hear (or usually see on a spectrogram) the individual clicks. Sometimes these sounds are used for *echolocation* and sometimes they're used for *communication*. Burst pulses can sound *many different ways*. They can sound like *creaks, buzzes, squeaky door hinges, squeaks* or like many *other* different things.

Scientists can also use spectrograms *measure sounds*. They can measure things like how long a sound is (*duration*), how high the pitch goes (*maximum frequency*), how low the pitch goes (*minimum frequency*) and what the *starting* and *ending* frequencies are. On the next page you will see an example of some *measurements* on a spectrogram:



Using these measurements, scientists can *learn* what different species sound like and how they *communicate*,  they can *compare species* to each other and even compare sounds made by the same species in *different places*. A lot of species sound different in different parts of the world!

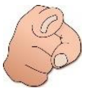
Different kinds of marine mammals make different kinds of sounds and these sounds all *look*  different on spectrograms. Here are some sounds made by *fin whales* and *blue whales*:



These sounds are all very *low frequency* – they are so low that they are **VERY HARD** or even **IMPOSSIBLE** for people to hear! 

Some questions for you…

1. What are some things that you notice  about this spectrogram?
2. What is the highest frequency on the spectrogram?
3. What are some differences between the blue whale sounds and the fin whale sounds?

There are many different **computer programs**  that scientists, students,  and even **you**  can use to make spectrograms from sounds. Some of the programs are **free** and some you have to **pay for**.  Here are **links** to some computer programs that can be used to make spectrograms:

Raven (free lite version, full version for purchase): http://www.birds.cornell.edu/brp/raven/RavenOverview.html

Ishmael (free): http://www.bioacoustics.us/ishmael.html

Pamguard (free): https://www.pamguard.org

Avisoft SASLab (free lite version, full version for purchase): https://www.avisoft.com/soundanalysis.htm

Audacity (free): https://sourceforge.net/projects/audacity/

Adobe Audition (for purchase): https://www.adobe.com/uk/products/audition.html

Here are some fun webpages  all about sound:

All about sound: https://www.dkfindout.com/uk/science/sound/

Discovery of sound in the sea: https://dosits.org/

Sounds of the sea: http://marinebio.org/oceans/sounds-of-the-sea/

Exploring whale sounds: http://www.listenforwhales.org/page.aspx?pid=444

Recordings of underwater sound:
https://oceanexplorer.noaa.gov/gallery/sound/sound.html

Acoustic recordings, videos, games, lesson plans all about marine mammal acoustics:
http://cetus.ucsd.edu/voicesinthesea_org/index.html

Appendix A and Appendix B of the **Raven User's manual** are very good **introductions to recording sound and creating spectrograms:** http://www.birds.cornell.edu/brp/raven/Raven14UsersManual.pdf

Answers to the questions about the blue and fin whale spectrogram:

1. The spectrogram has a different colour scheme than the other spectrograms. It only shows the low frequencies. The spectrogram is 90 seconds long.
2. The highest frequency is **400 Hz**
3. The blue whale sounds are long and thin, like dolphin whistles. 
   The fin whale sounds are short and tall, like dolphin clicks.