# Bird Song Bioacoustics-Physics and Bird Song

**Goal:** Students understand how birds make songs and that scientists can identify songs by visualizing them in special graphs called spectrograms.

**Objectives:**
- Learn to recognize high and low frequency sounds
- Understand that spectrograms are visual representations (models) of sound
- Recognize that bird songs vary in frequency and pattern

**Big Idea:** Scientists study and can identify different bird songs using special graphs called spectrograms.

**Virginia SOL** Science (2018) 5.5

**Science Concepts**

| | | | |
|---|---|---|---|
| Sound | Vibration | Frequency | Pitch |
| Wave | Wavelength | Compression | Amplitude |
| Energy | Spectrogram | Hertz | Kilohertz |
| Ornithologist | Vocal cords | | |

## Bird Song Bioacoustics Lesson Overview

**INQUIRY DISCUSSION/REVIEW**

1. **What is sound?** Something we hear; something we make.
   **How do scientists describe sound?/What is sound to a scientist?**
   a) Explore sound frequency and how sound waves change as frequency changes from low to high
      Oscillator: https://musiclab.chromeexperiments.com/Oscillators
      Low sound: low frequency; sound waves far apart
      High sound: high frequency; sound waves close together
   b) Sound is a type of wave: a compression wave. Sound is a form of Energy. Sound is vibrations.
      **SHOW**: Cornell Lab "Bird Song Visualized", slides 1 & 2 (sound vibrations; sound amplitude and sound wave)
   c) Sound is vibrations: Slower the vibrations, lower the frequency; Faster the vibrations, higher the frequency
      **SHOW** Chrome Music Lab, Sound Waves: https://musiclab.chromeexperiments.com/Sound-Waves
      How does sound get to our ears? (Sound is vibrations that travel in waves through air/other substances.)
   d) **Are all sounds the same?** No **How were the sounds different?**
      Loud vs. Soft = Amplitude
      Low vs High = Frequency (frequency is measured in hertz; pitch is measured in notes & octaves (Note A, Octave 4 = frequency 440 hertz)
      Frequency: 1 hertz = 1 cycle/second; 1 kilohertz = 1000 cycles/second
2. **Make Sound Visible https://musiclab.chromeexperiments.com/Spectrogram**
   a. Wine glass:
      a. Are all the sounds the same? How are they different? Some are low; some are high. Where are the low sounds drawn (bottom)? Higher sounds? Above
      b. Person Whistling:
   b. Are there high and low sounds? If you could not hear them, could you still identify which sounds were low and which were high?
   c. What is special about the sound line that goes from high to low?
      a. 3) Microphone:
   d. Make a low sound
   e. Make a high sound
   f. Make a sound like the whistle that goes from low to high; high to low
      a. 4) Drawing a sound graph
         a) Tell me what type of sound to draw (high, low, rising, falling)

**EXPLORE BIRD SONGS**

3. **How do humans make sounds? Have students make sounds & feel the vibrations of their vocal cords**. Place your hand on the front of your neck (over your vocal cord). Say AH: What do you hear? What do you feel? Do you feel vibrations? When you say AH, your vocal chords vibrate creating sound. These sound waves travel through air to our ears. Try a higher pitch AH, and a lower pitch AH.

4. **Connect to the sound mapping activity held outdoors.** When you first began to listen, what did you focus on? The second time, what did you focus on? Did you find ways to isolate (or pick out) certain sounds?
    a) **<u>Morning Bird Song Chorus</u>. Play the bird sound audio embedded in the slide. Bird scientists (ornithologists) study bird sounds or bird songs.** Bird songs are important sounds for a bird scientist; bird songs help to locate, identify, and study bird behaviors
    b) **<u>Bird Scientists Slide</u>.** Ornithologists use bird songs to study bird populations, find geographic variance in song (dialects, relate this to human dialects, Alabama versus West Virginia versus Midwest accent), & monitor breeding habits. How do ornithologists record bird song? (Slide with Photo of bird scientists recording bird songs)
    c) **<u>Why do you think a bird sings</u>?** It is telling other birds what type of bird it is and where it is. Other types of communication can be: (a) Hi girls, I would make a good husband! (b) Watch out! There is danger nearby! (c) Don't come over here because this is my territory!

5. **How do birds make sounds**? Play the Cornell "How Birds Sing" to show how birds use both sides of their vocal cords to make sounds. Birds can alternate sides of the syrinx or can make two sounds at the same time. Sound travels and vibrates the syrinx of birds. 4 examples
   https://academy.allaboutbirds.org/features/birdsong/how-birds-sing

6. **Making sounds visible.**
   a) **<u>Willow warbler spectrogram example</u>**. *What is the x-axis?* **Time**
      *What is the y-axis?* ***Frequency****.*
      *How many different notes do you see?* ***2*** *How many total notes?* ***6***
      *Now that you know about the structure of a bird's vocal cords, how can this bird sing two different notes at the same time?* ***The bird's vocal cord has two sections; one note is made in each section of the vocal cord.***
   b) **<u>Example spectrograms of the wine glass, one or two other musical instruments</u>**. What happens to the spectrogram when the notes are low in frequency; high in frequency?

**<u>Use Hand icon to select our own notes</u>**. Have students suggest whether a note should be low frequency or high frequency. Play with different patterns (such as one note going form low to high frequency).
**<u>Use microphone icon to record our own sounds</u>.**

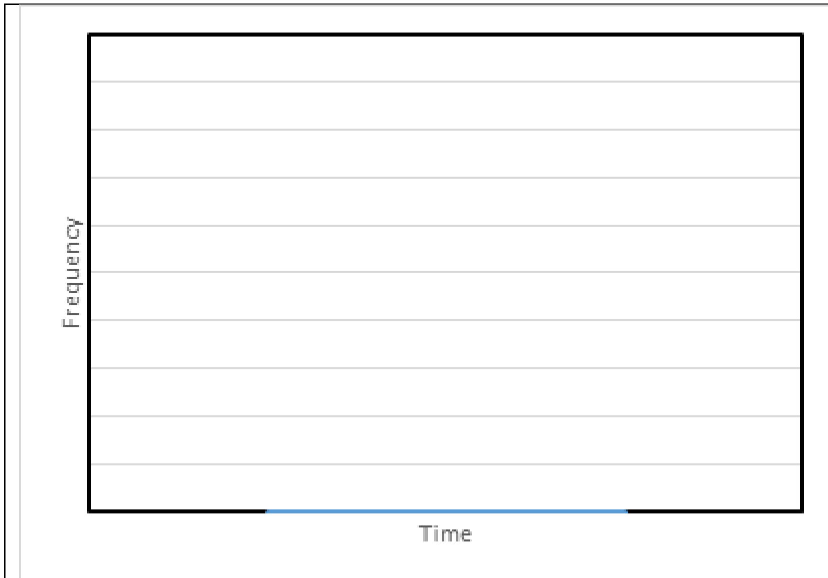
7. **Frequency Graphs** (Bird Song Bioacoustics, slides 13 through 18).
Play the constant tone and ask for predictions on what the graph will look like (Data sheet, spectrogram # 1). Play the pulse tone and ask what that should look like (Data sheet, spectrogram # 2). Have students draw what they think the spectrograms should look like on their data sheets.

8. **Aural & optional Kinesthetic Activity** (Bird Song Bioacoustics, slides 19 through 24).
   a) **<u>Aural. Sing-a-long-spectrogram</u>**! Divide the class into two groups and have them sing the sound pattern shown on the different spectrograms.
   b) **Kinesthetic.** Match the frequencies through movement and sound. Ask students to predict what the spectrograms sound like. Use this time to ask the teacher to squat down, move up to tip toes, trail from side to side, rising as they go. Ask students to make sounds based on the teacher's movements.

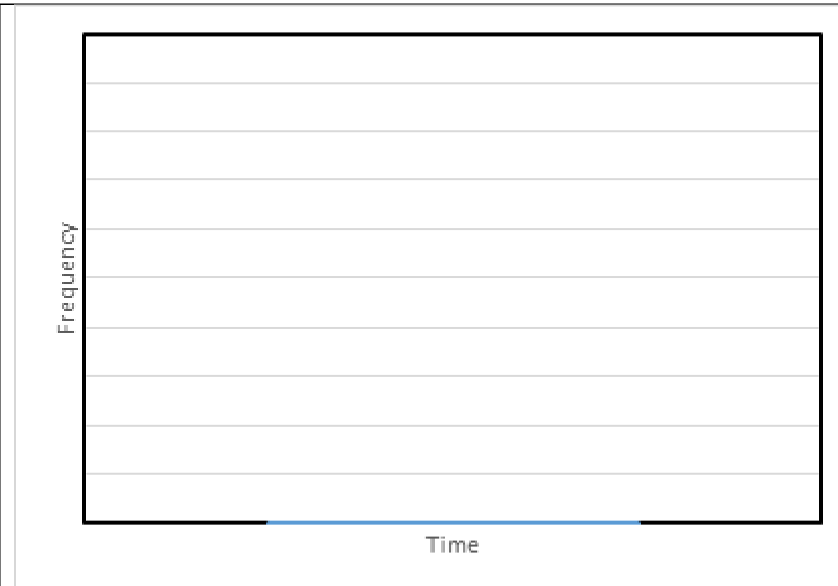
9. **Data Sheet; Bird Song Graphs.** (Bird song Bioacoustics, slides 25-31) Students listen to the 3 different bird songs and draw what they think the spectrogram should look like. After each song, show the spectrogram. Remind students to think about whether the song is a high or low frequency, how the frequency changes, how many types of notes the bird is singing, the pattern of the notes, etc. Do this with the three birds.

10. **Learning to sing**. Cornell sound recordings with spectrograms of adult & juvenile birds. Even birds need to practice to learn how to sing correctly! There are 4 bird examples and one example of a toddler and adult human. Play as many examples as time permits.
https://academy.allaboutbirds.org/features/birdsong/practice-perfect

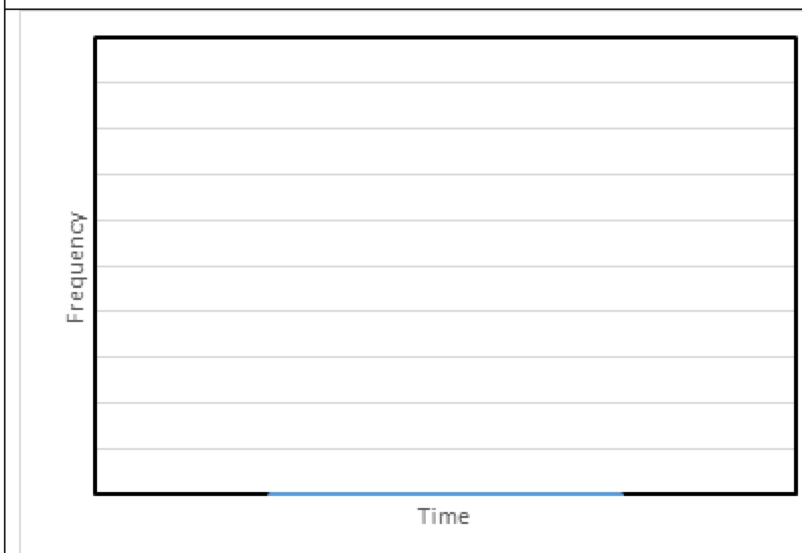
11. **Conclusion/Summary.** <u>Open-ended inquiry</u>: Ask students to share something they learned about sound during the class.

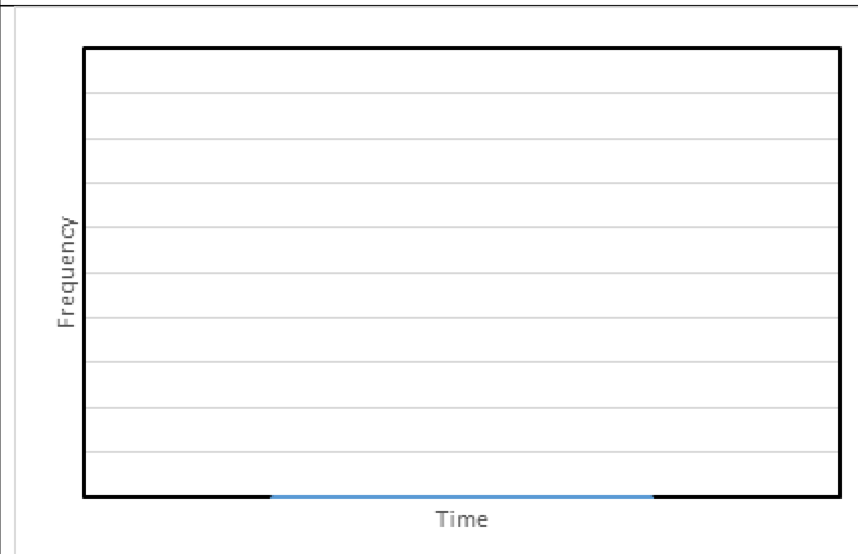



**1. Constant frequency note**



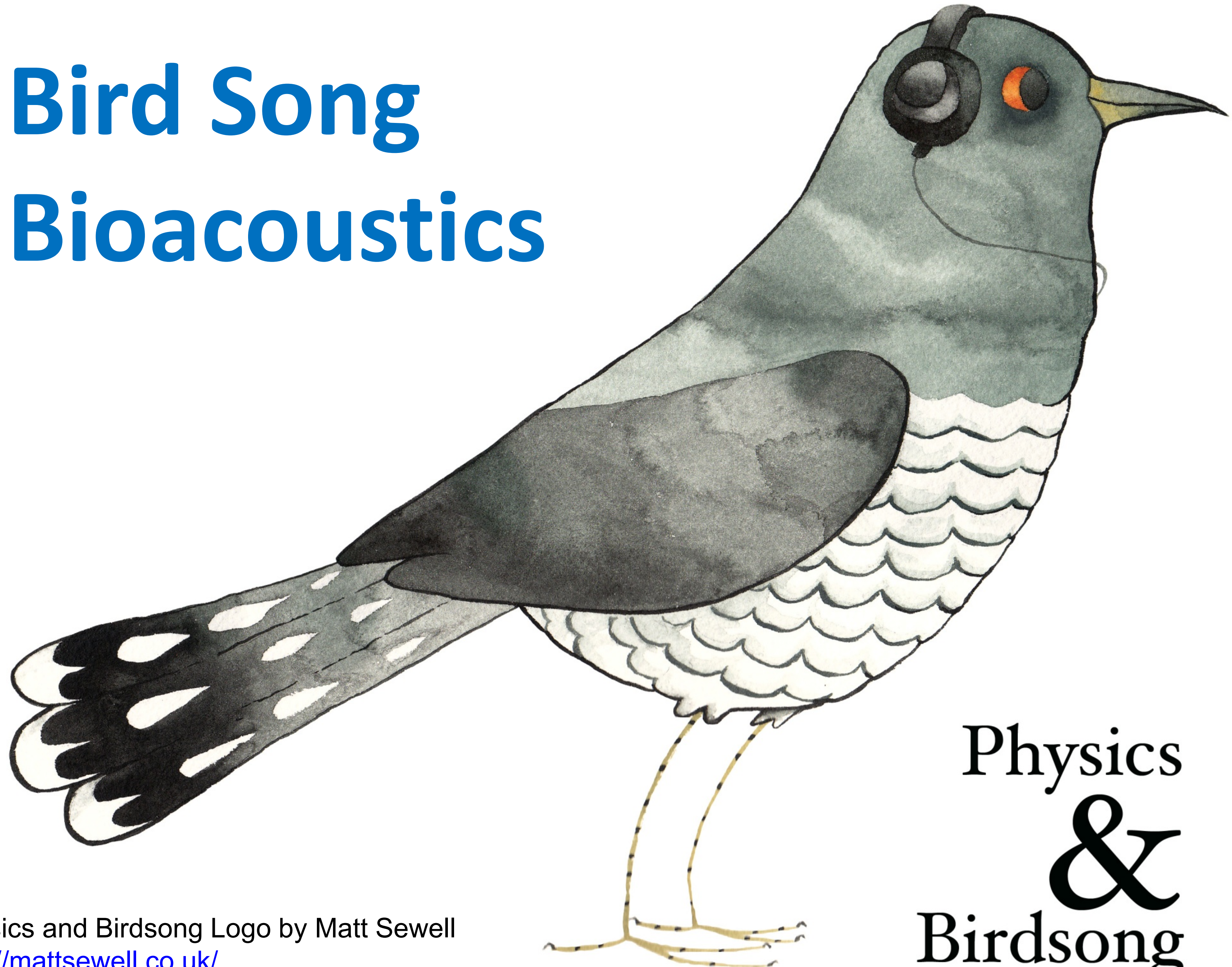

**2. Two notes of constant frequency with a pause**



| 3. Chiff chaff (a type of bird) spectrogram | 4. Willow warbler (a type of bird) spectrogram |
|---|---|
| | |

# Bird Song Bioacoustics



Physics & Birdsong

Physics and Birdsong Logo by Matt Sewell
http://mattsewell.co.uk/

# Bird Scientists

# Frequency and Pitch

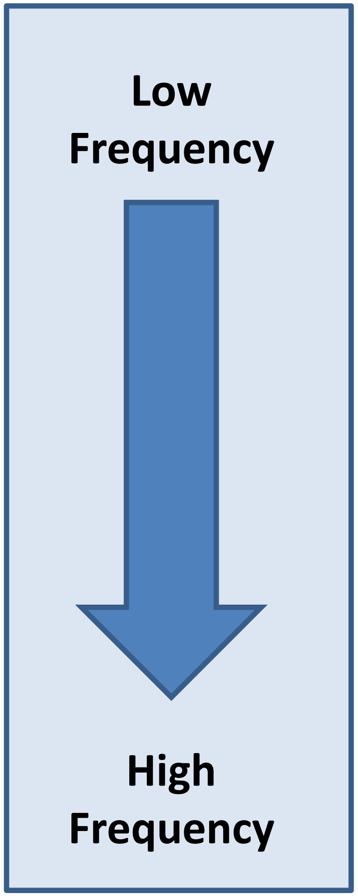
- Sound is caused by vibrations.
- The number of vibrations every second is called the **frequency**.
- Frequency is measured in Hertz (Hz).
- 1Hz = 1 vibration every second.
- 1kHz = 1000 vibrations every second.
- High frequency notes are heard as high pitched sound. The higher the frequency, the higher the pitch.

# How do we hear?

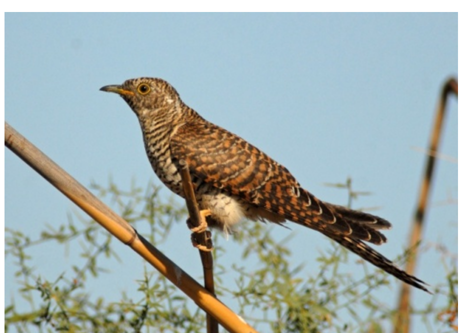
- When something vibrates, it makes the air around it vibrate.
- These vibrations are passed through the air quickly (340m/s).
- The vibrating air makes our eardrum vibrate which is how we hear sound.
- The air around the object making the sound **does not** end up in our ear, it is only the sound wave that travels to our ear. The air only moves backwards and forwards around where it was in the first place.

# Different birds, different songs

# What do songs of different frequencies sound like?

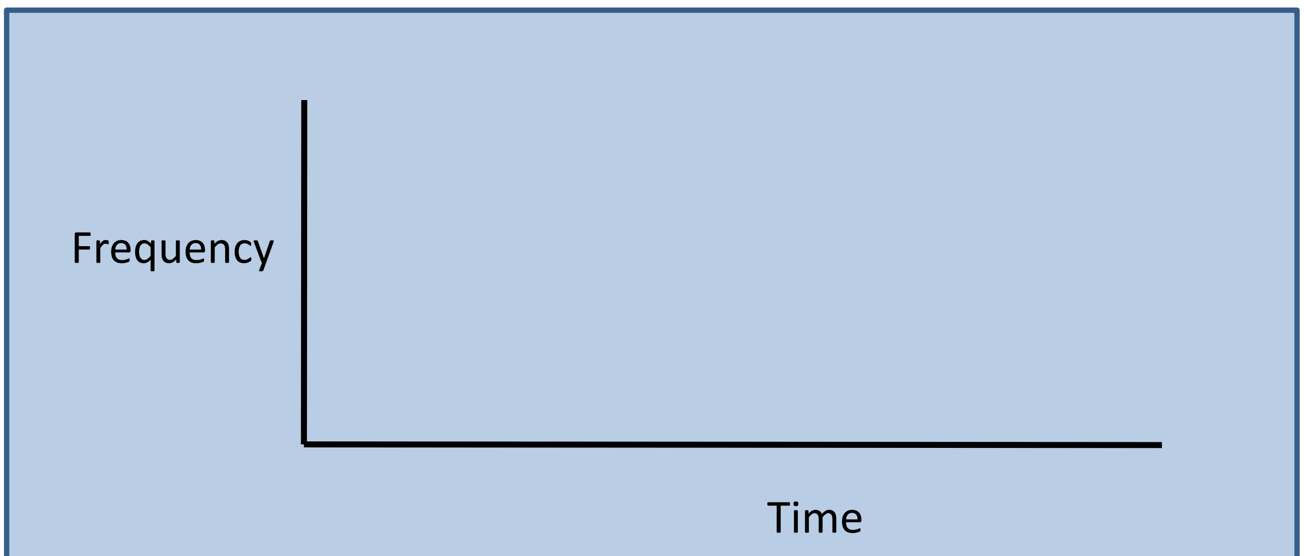



- The Common Cuckoo sings a bit above 500Hz (570Hz, 520Hz)
- The Common Sandpiper sings at about 5000Hz (4.8kHz)
- The Goldcrest is about 7kHz



# The spectrogram or sonogram

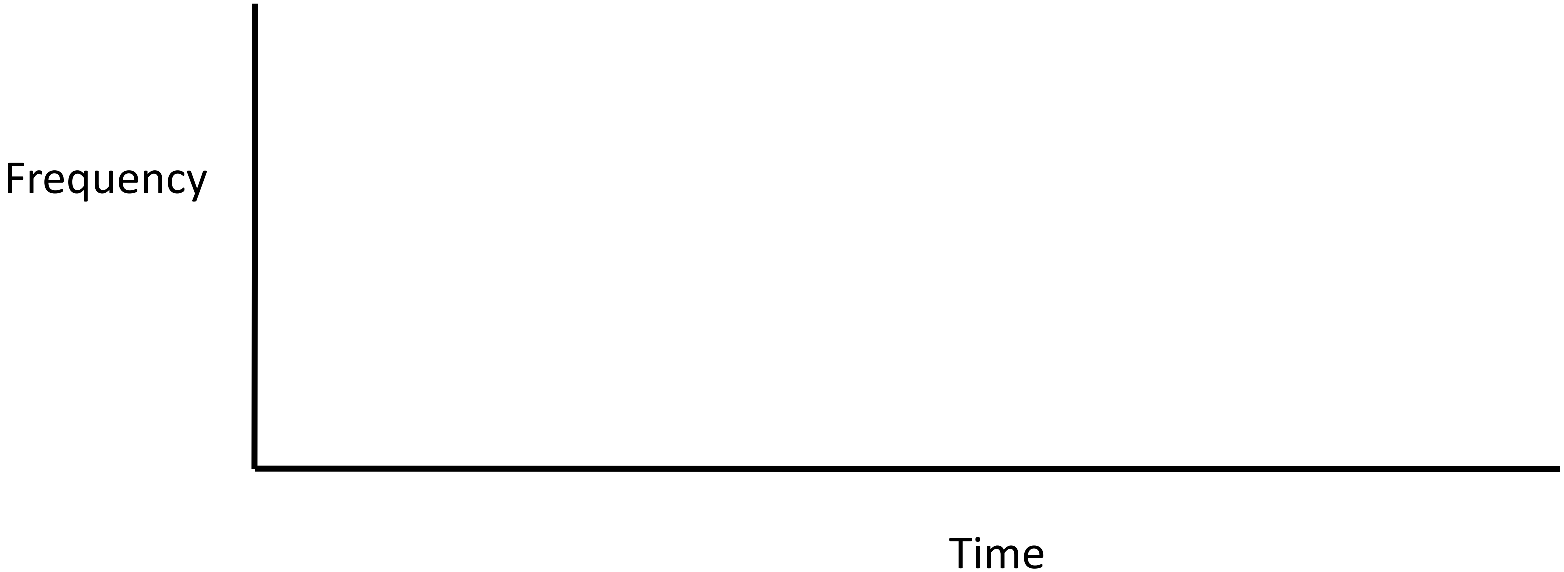
- A spectrogram is a way of drawing a ‘picture’ of a sound.
- It is a graph showing how the frequency of the sound changes over time.



# The spectrogram

An easy one to begin with:

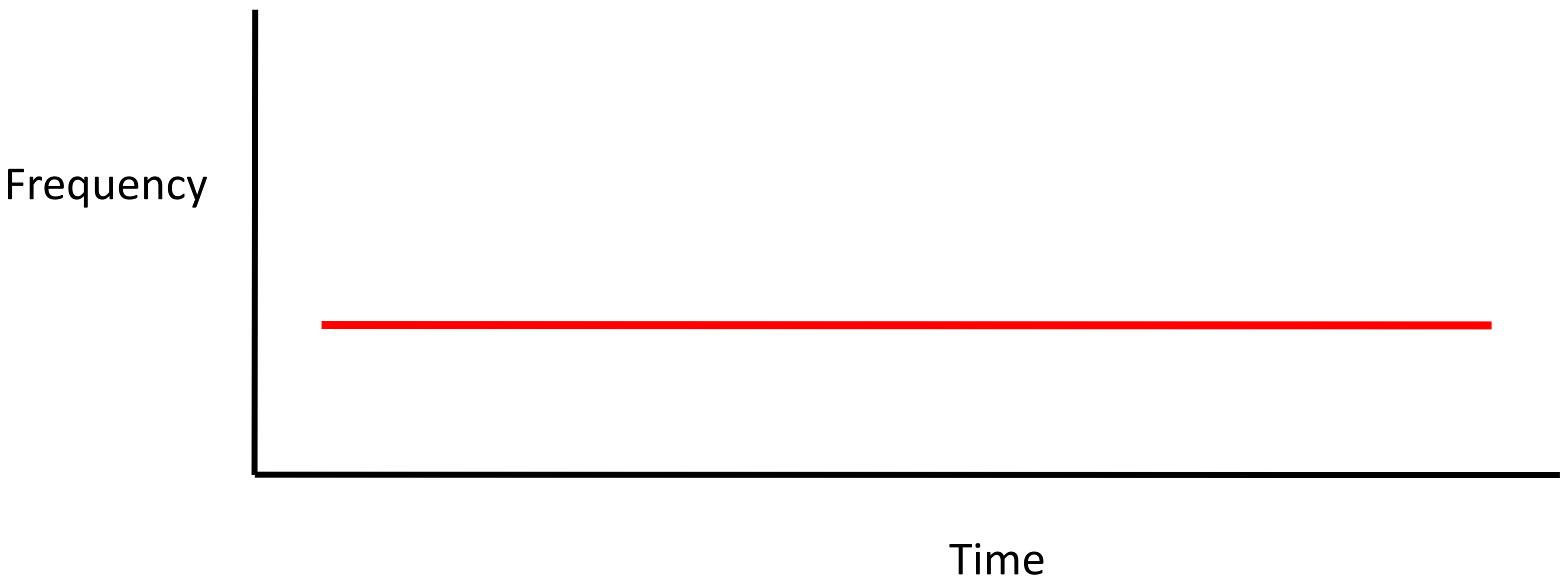
A note of constant frequency



# The spectrogram

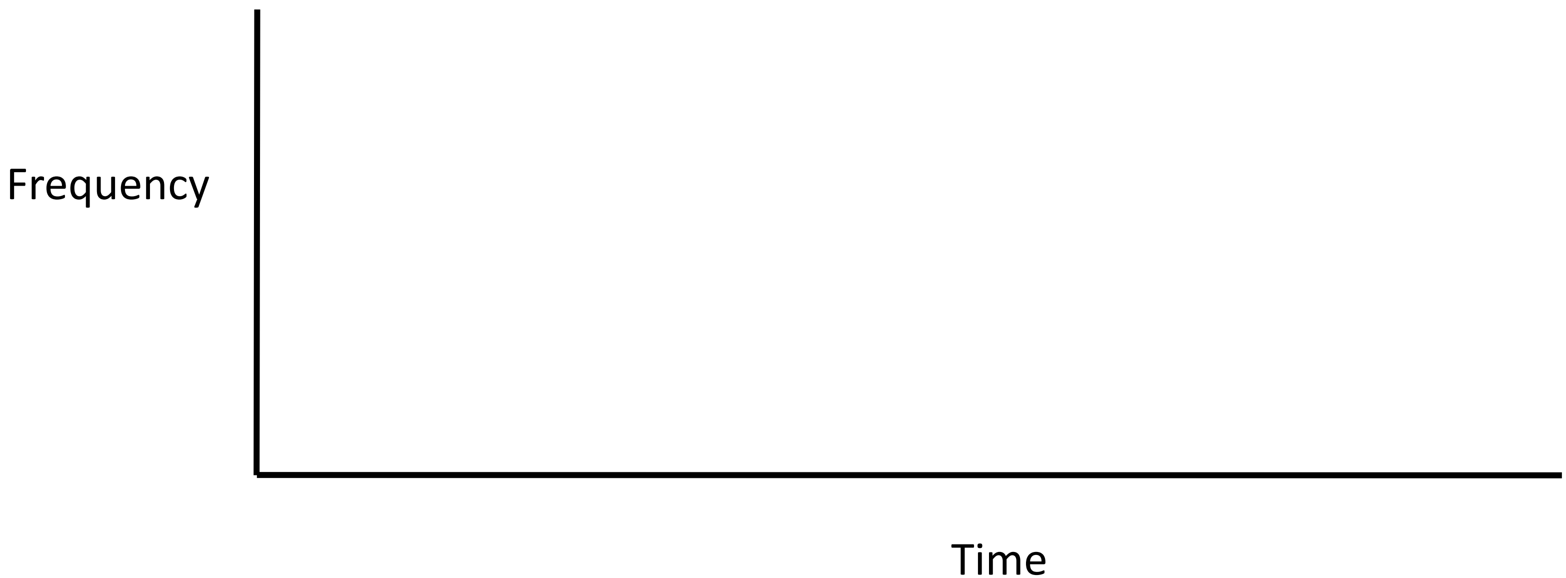
An easy one to begin with:

A note of constant frequency



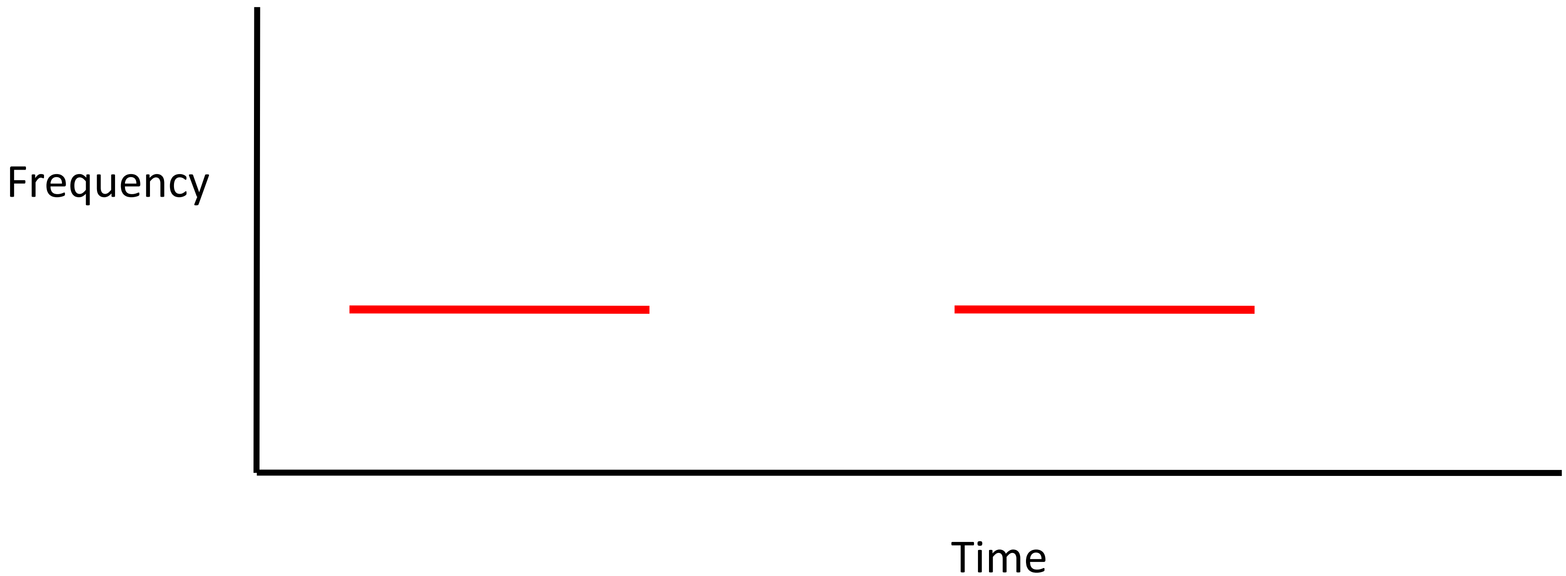
# The spectrogram

- The spectrogram shows changes with time
- A pulsed note of constant frequency



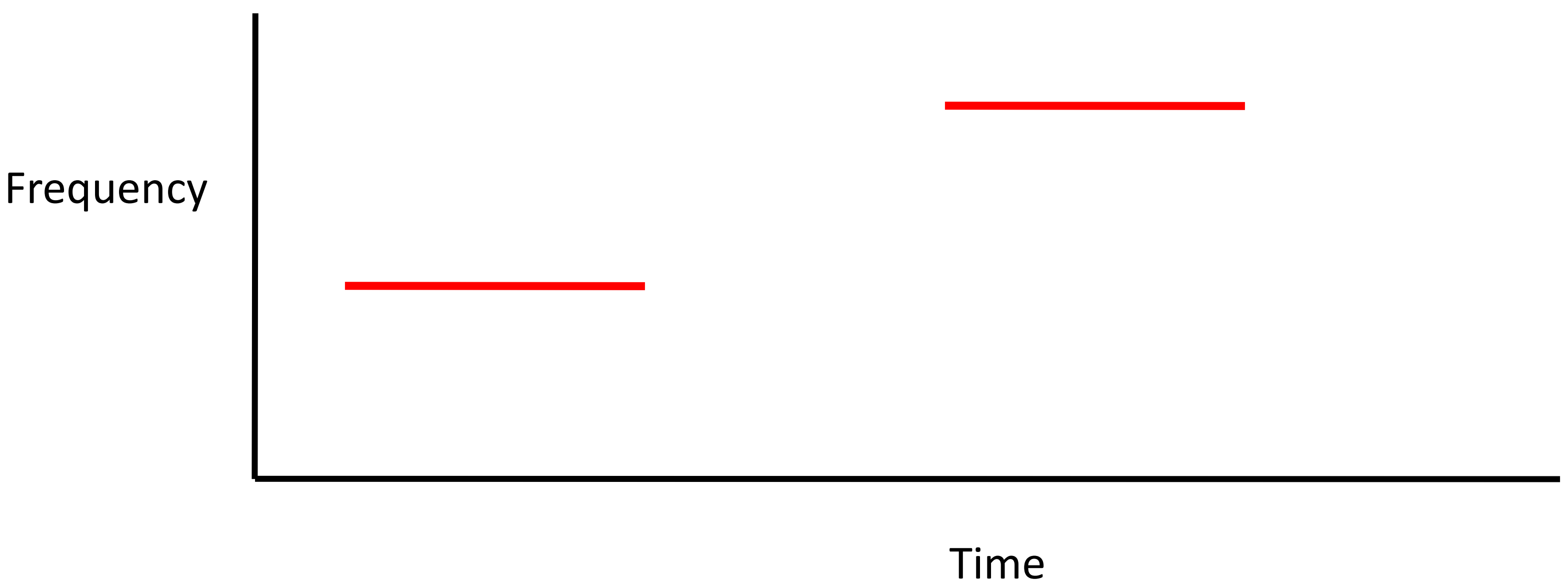
# The spectrogram

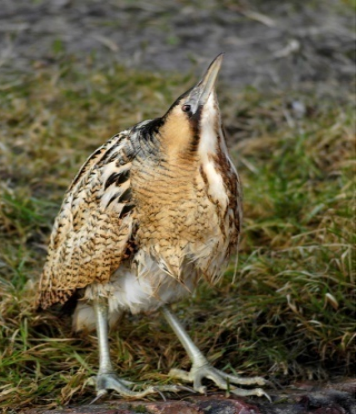
- The spectrogram shows changes with time
- A pulsed note of constant frequency



# Notes can go up as well as down

- Look at the graph and imagine what the sound will be like.



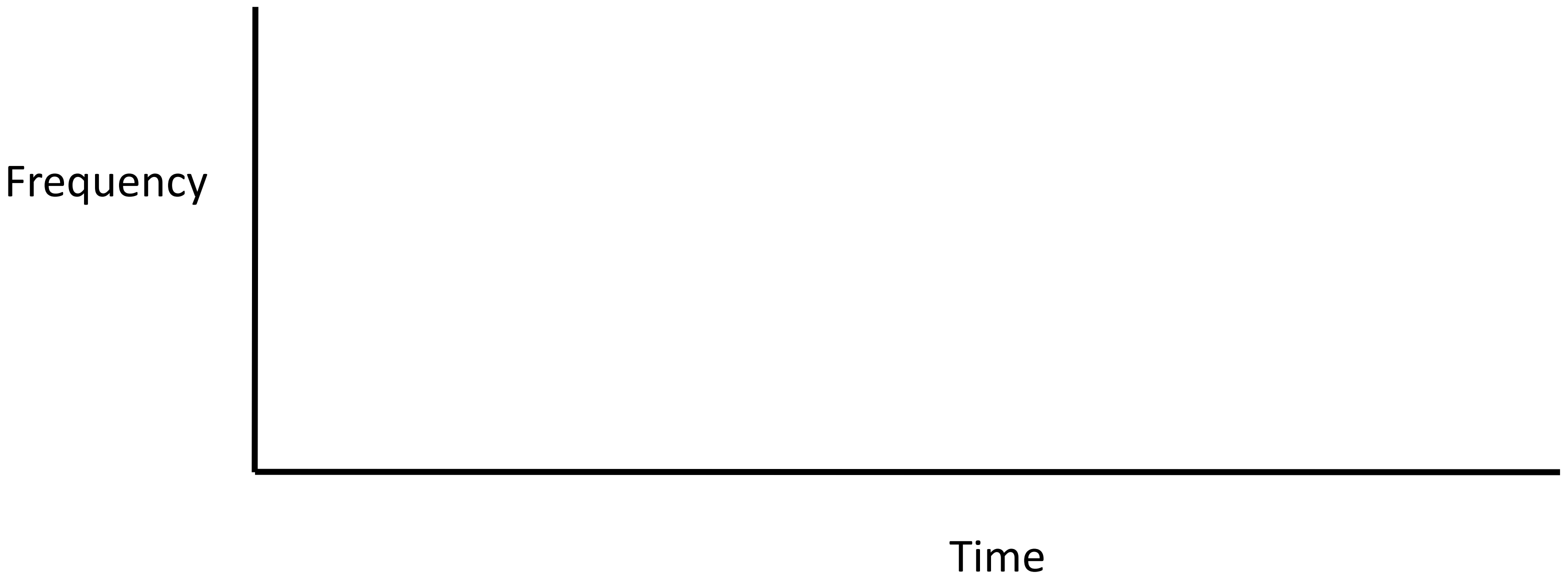



# Now to try with some real birds



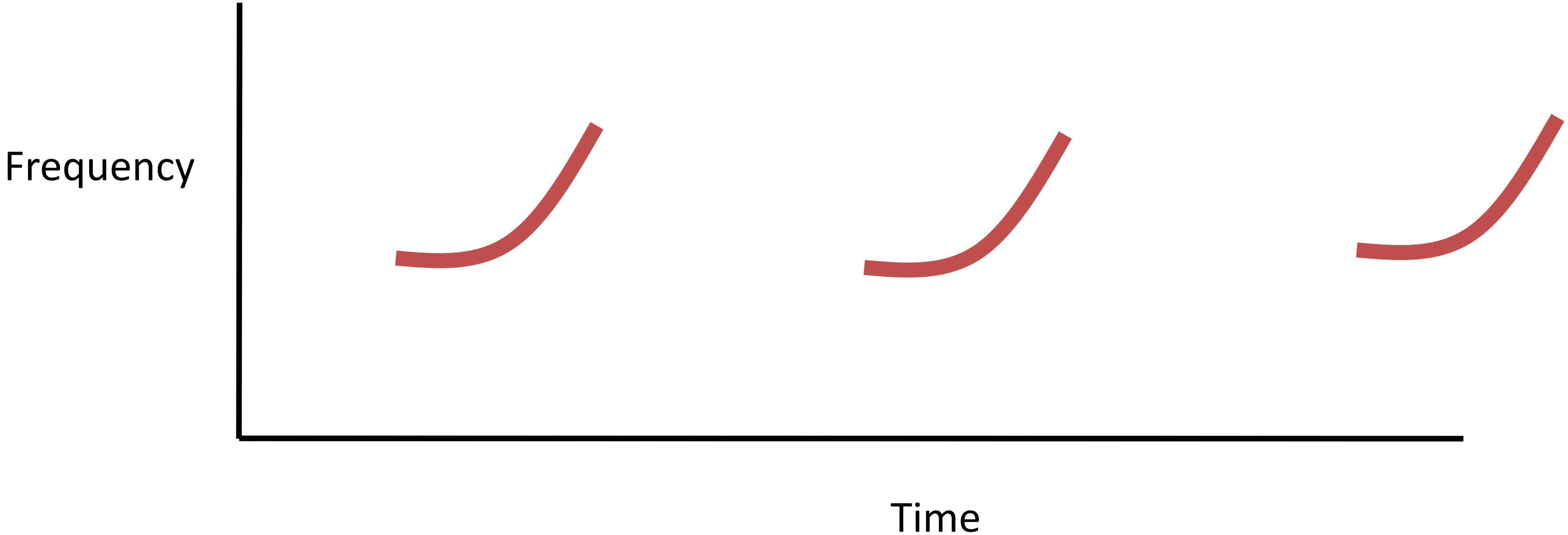

# The Willow Warbler

- Listen then try and draw the spectrogram



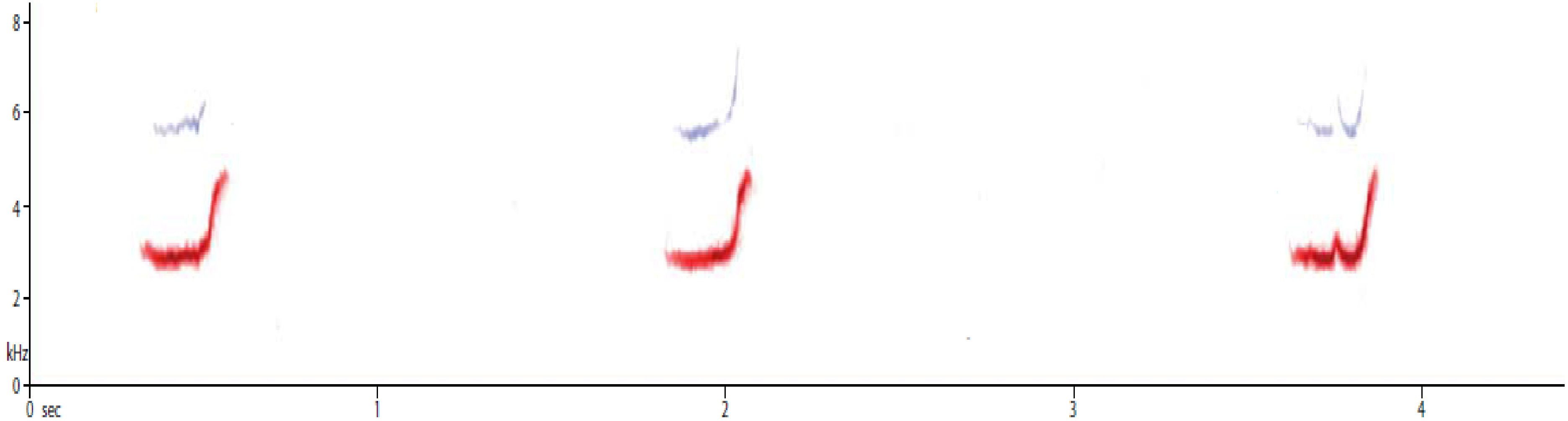
# The Willow Warbler

- Notes increasing in frequency



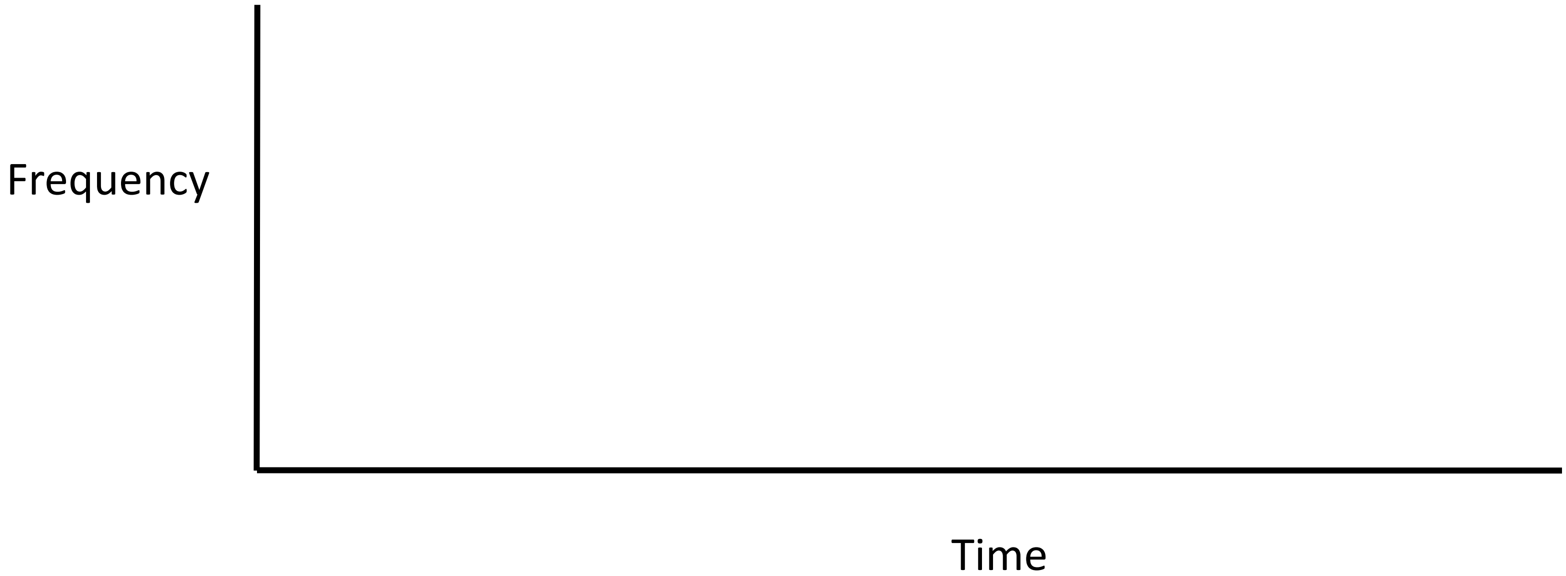
# The Willow Warbler

The full spectrogram is more complex but shows the same pattern.



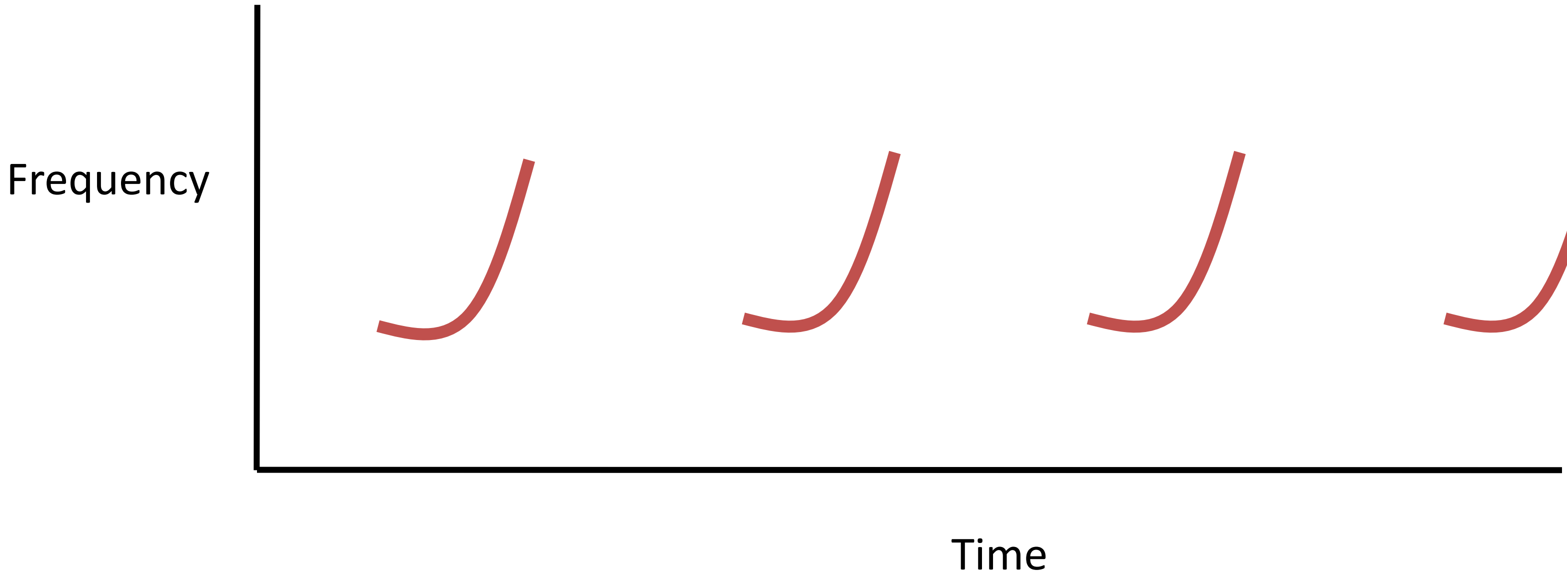
# The Chiffchaff

- Listen and sketch the spectrogram



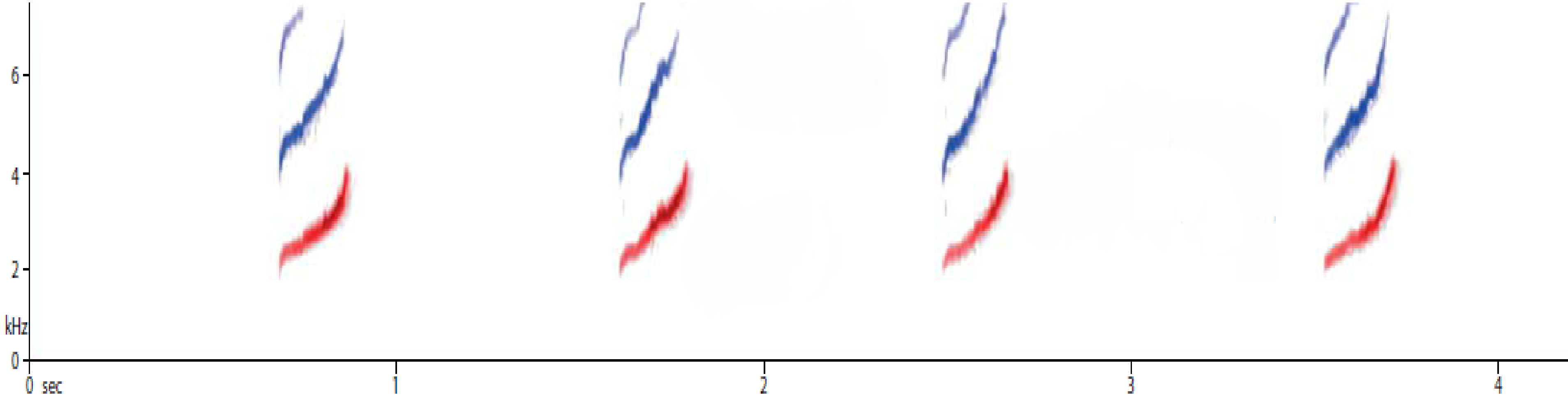
# The Chiffchaff

- The note is shorter and the frequency rises more quickly than the willow warbler

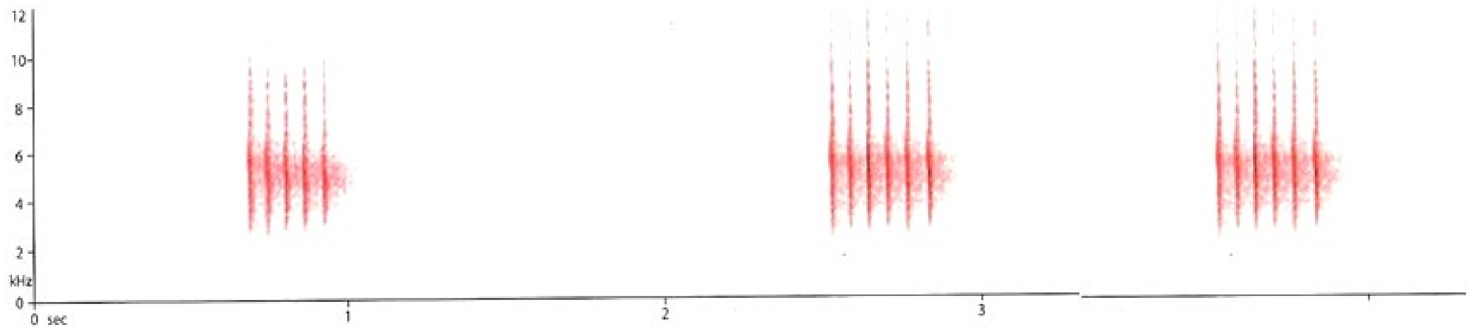


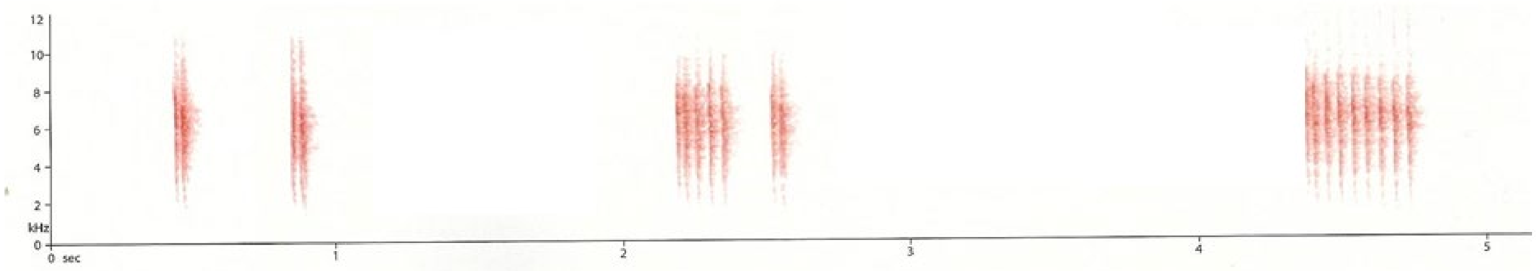
# The Chiffchaff

- The full analysis shows a similar but more complex pattern, rising from about 2kHz to 4kHz in a fraction of a second



# A quick quiz – which is which?

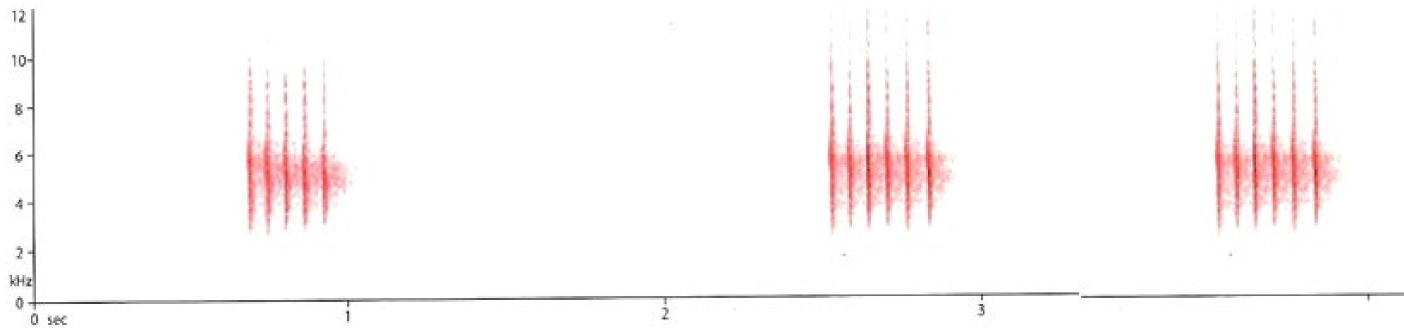


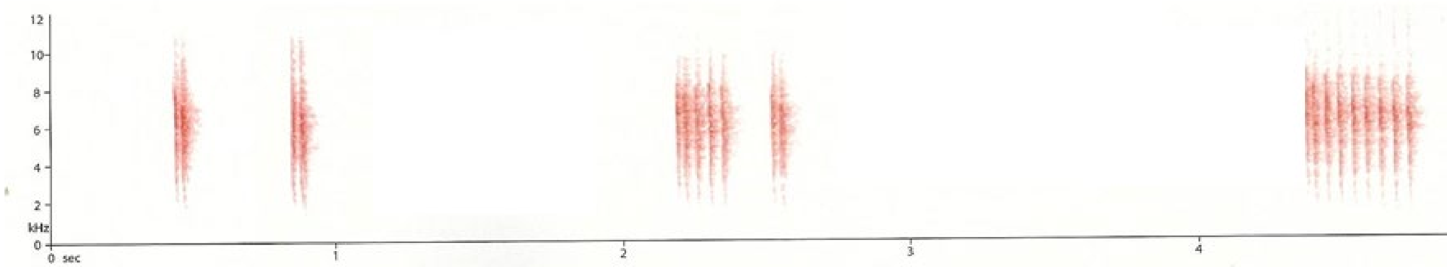

Winter Wren

Red-Breasted Flycatcher

# Which is which?

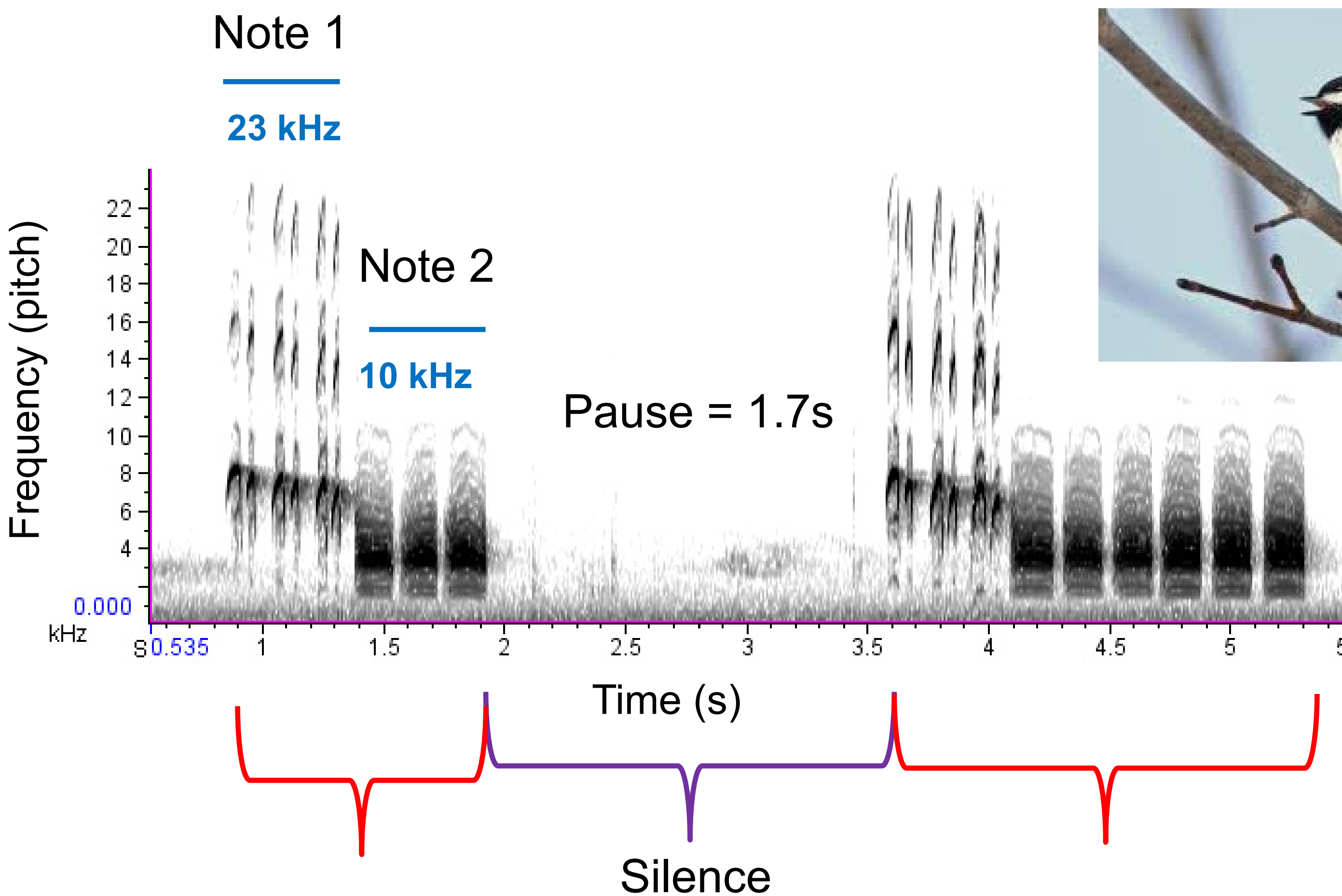



Red-Breasted Flycatcher




Winter Wren

# Spectrogram Analysis



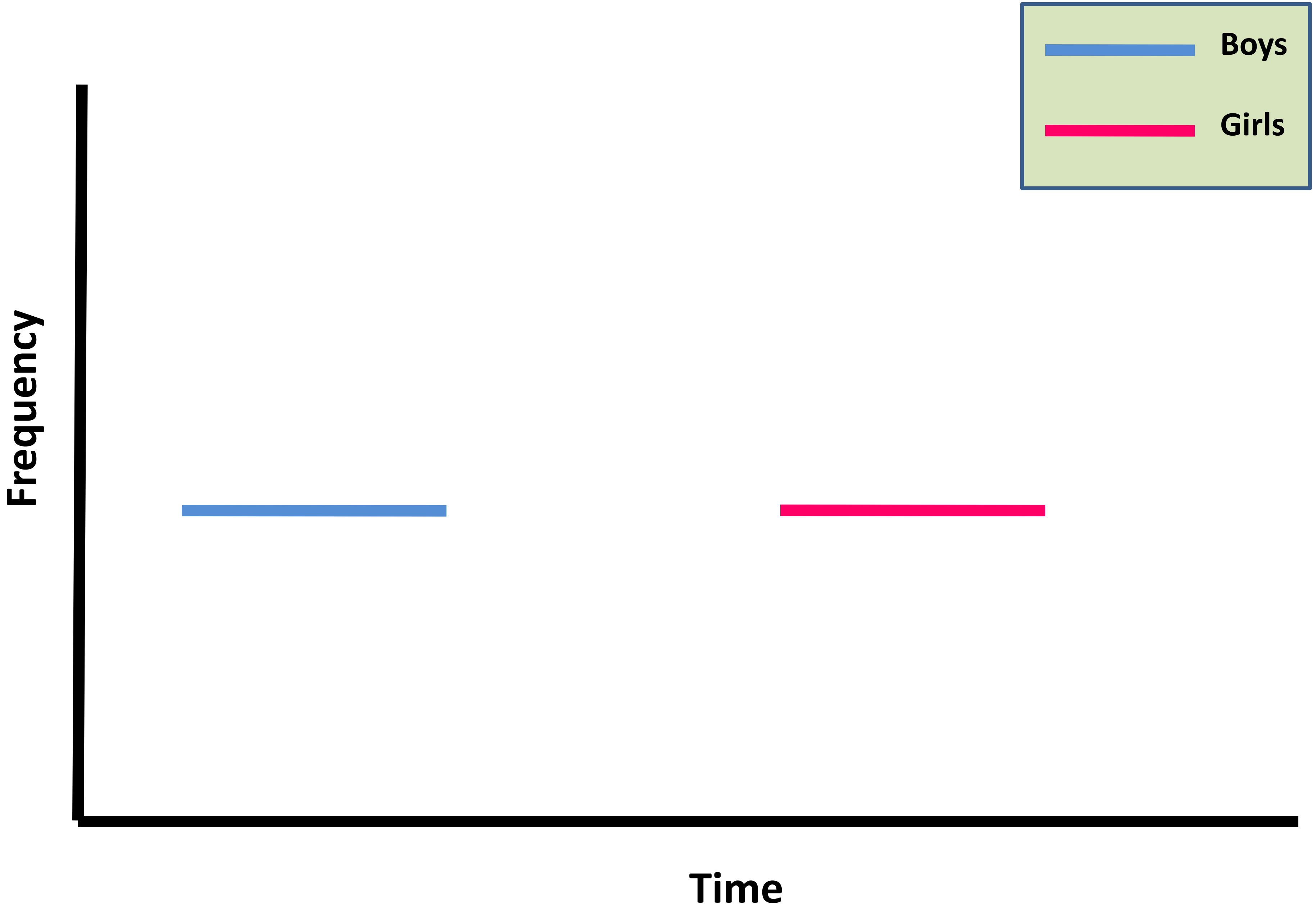

**Black-capped Chickadee**

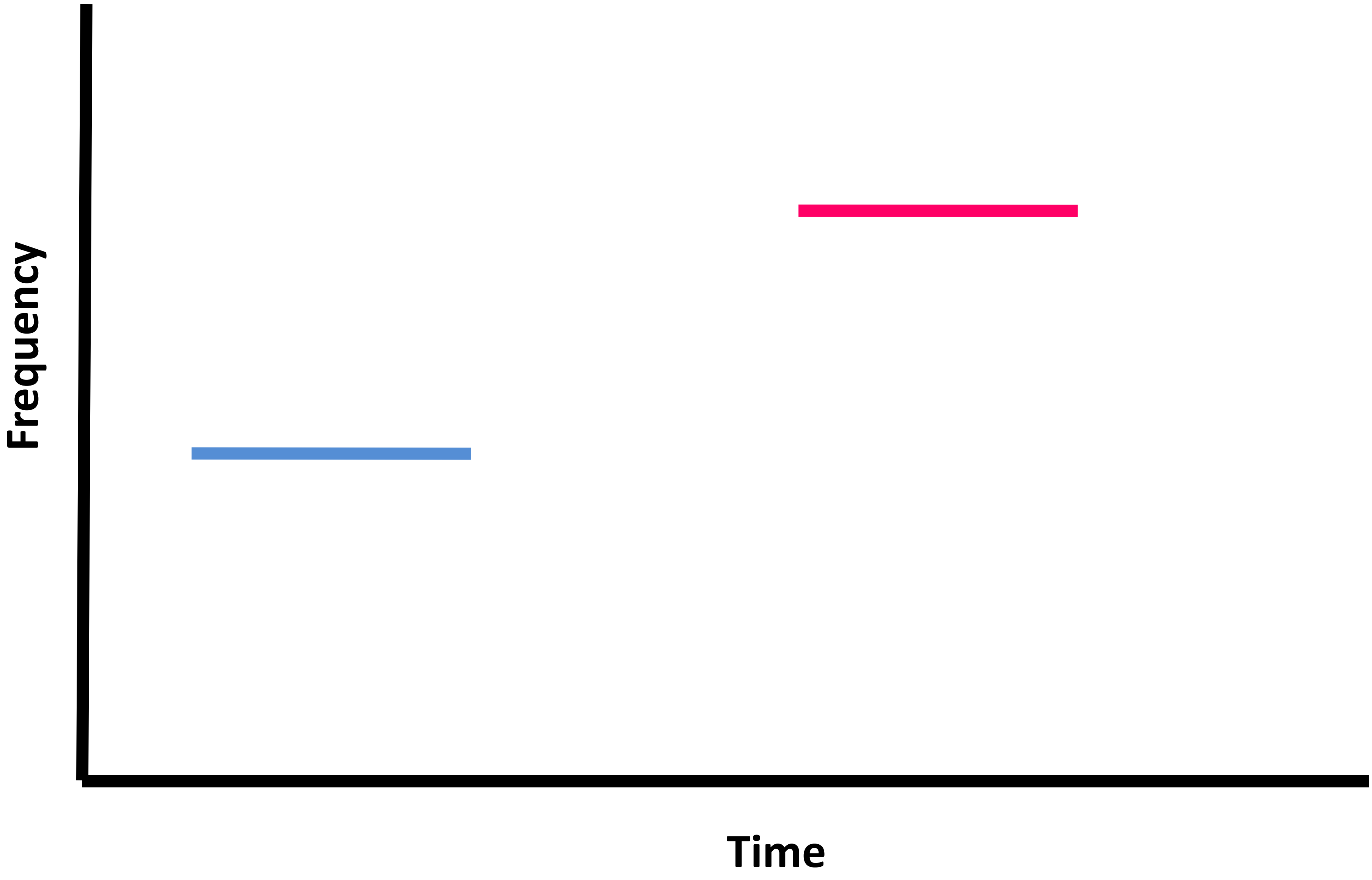
Note 1 repeats 6x; 0.05s each note

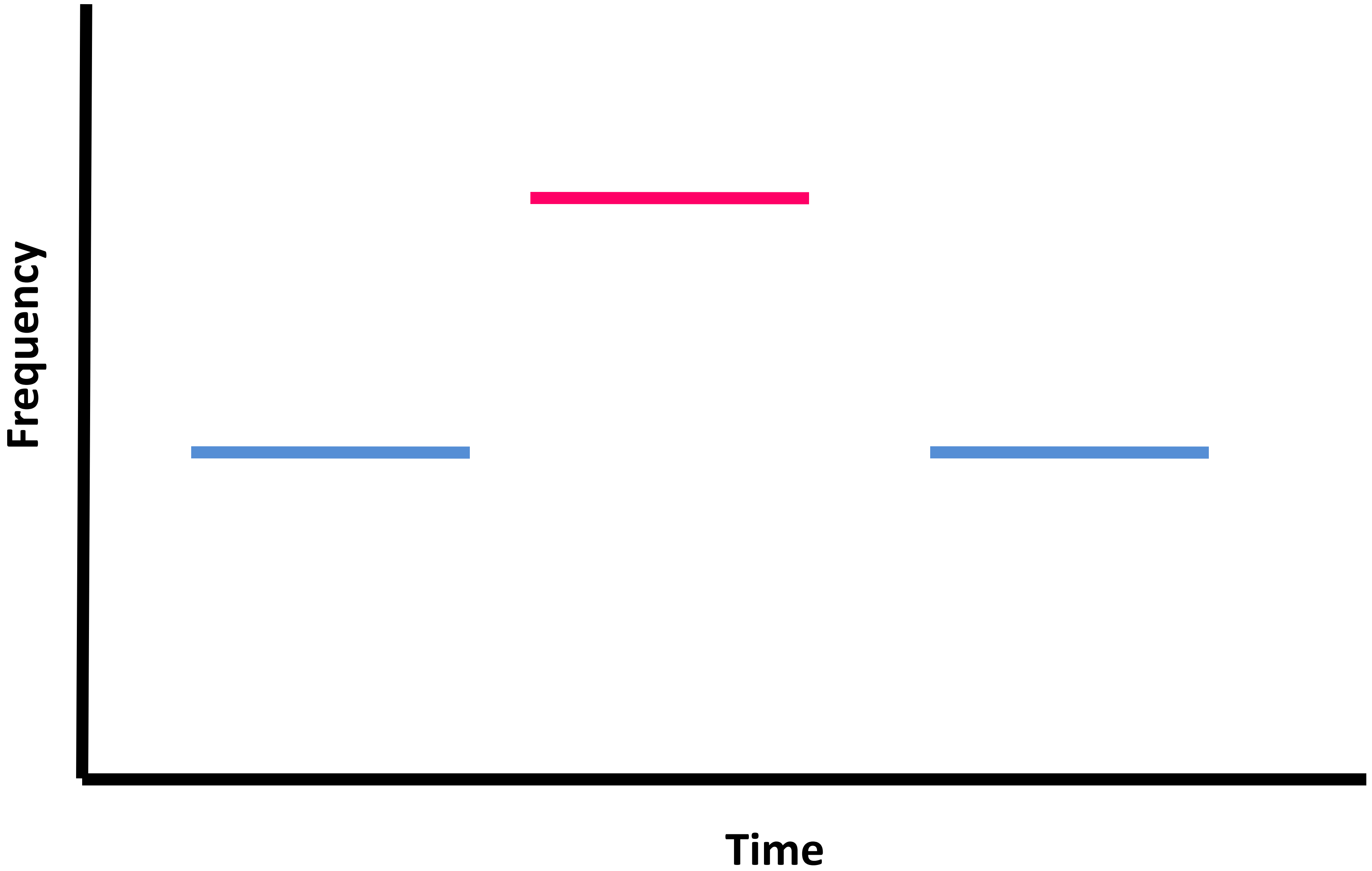
Note 2 repeats 3x to 6x; 0.15s each note

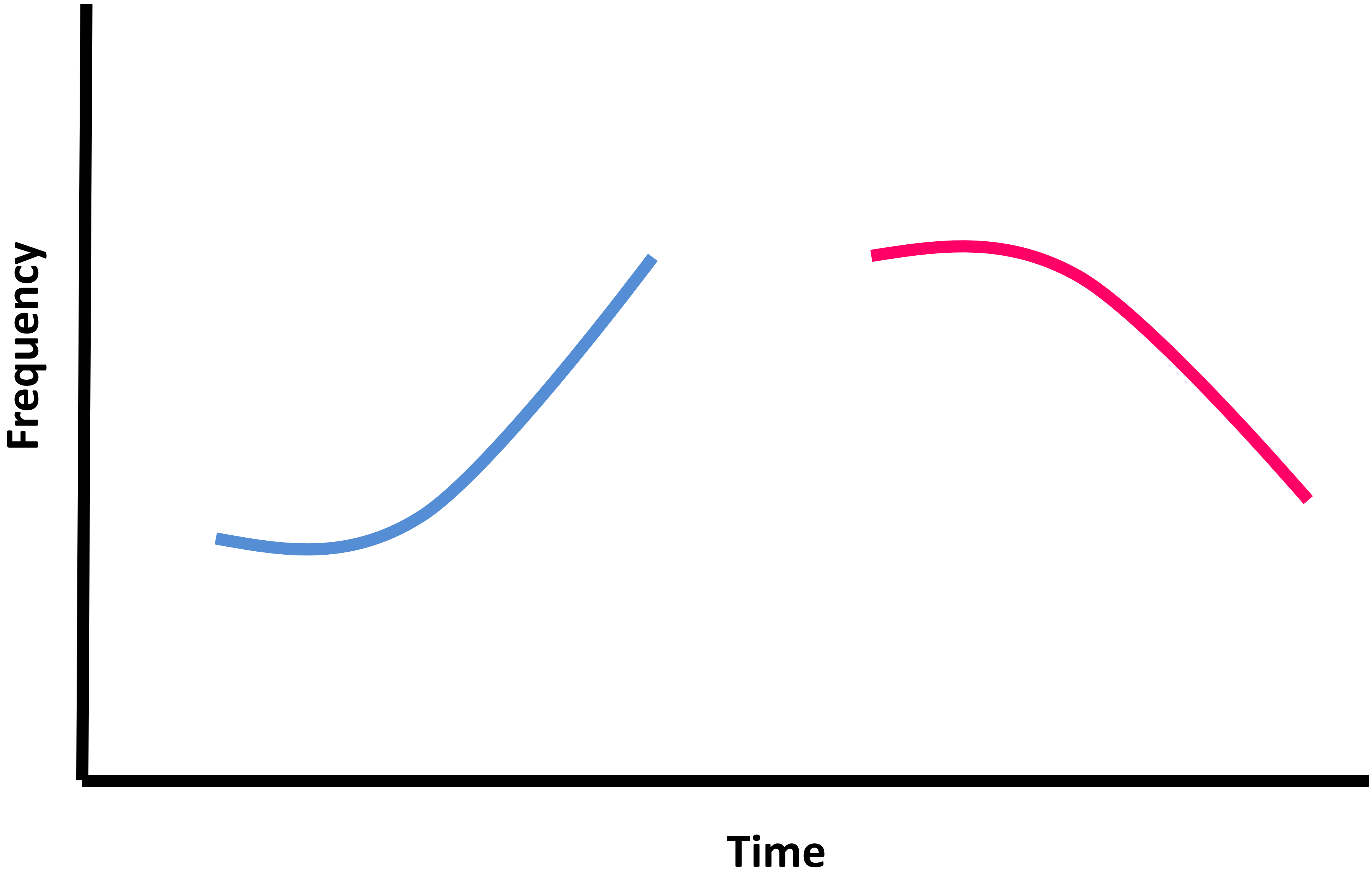
It’s time to play…

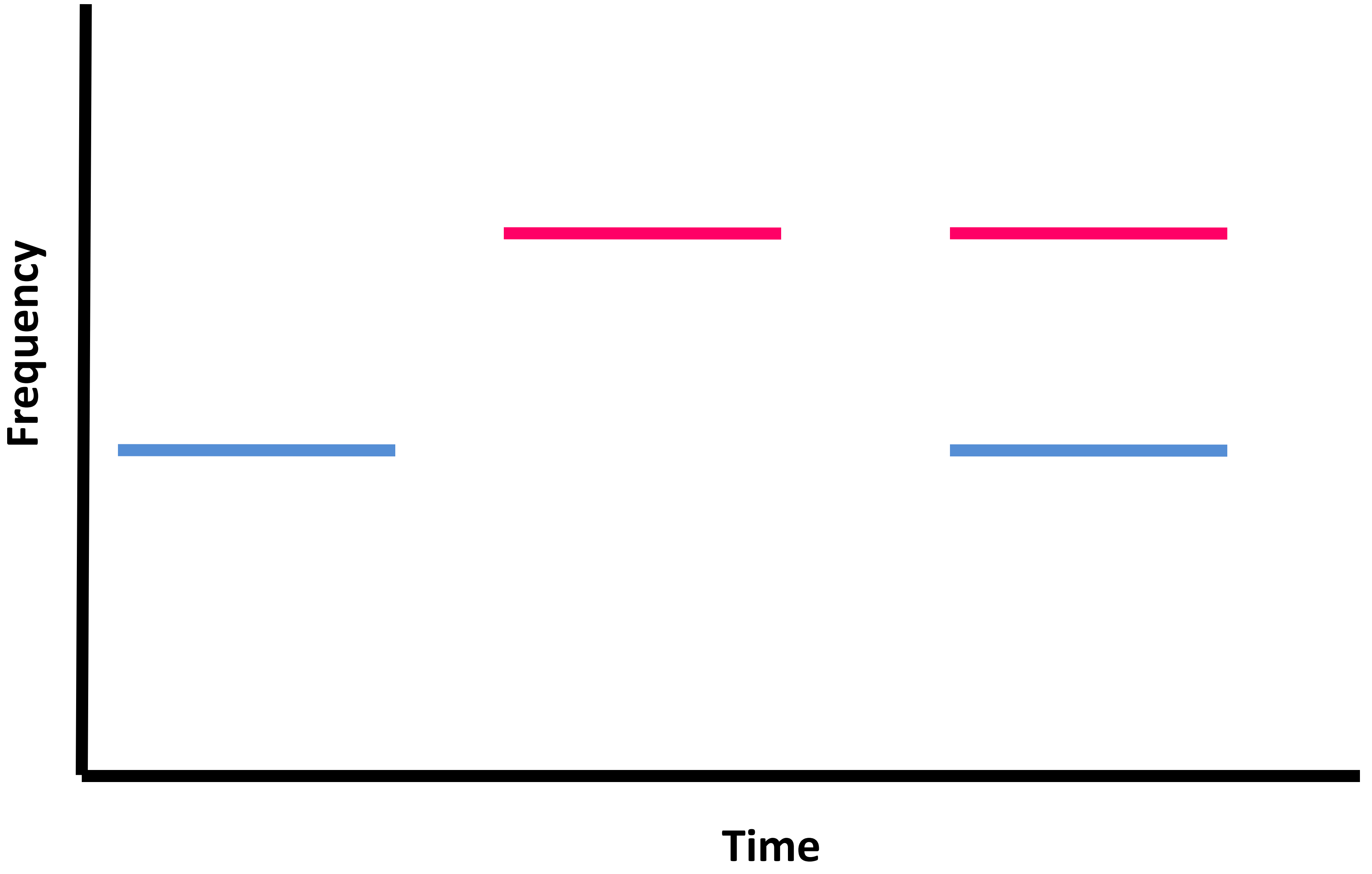
**Sing-a-long-a-sonogram**

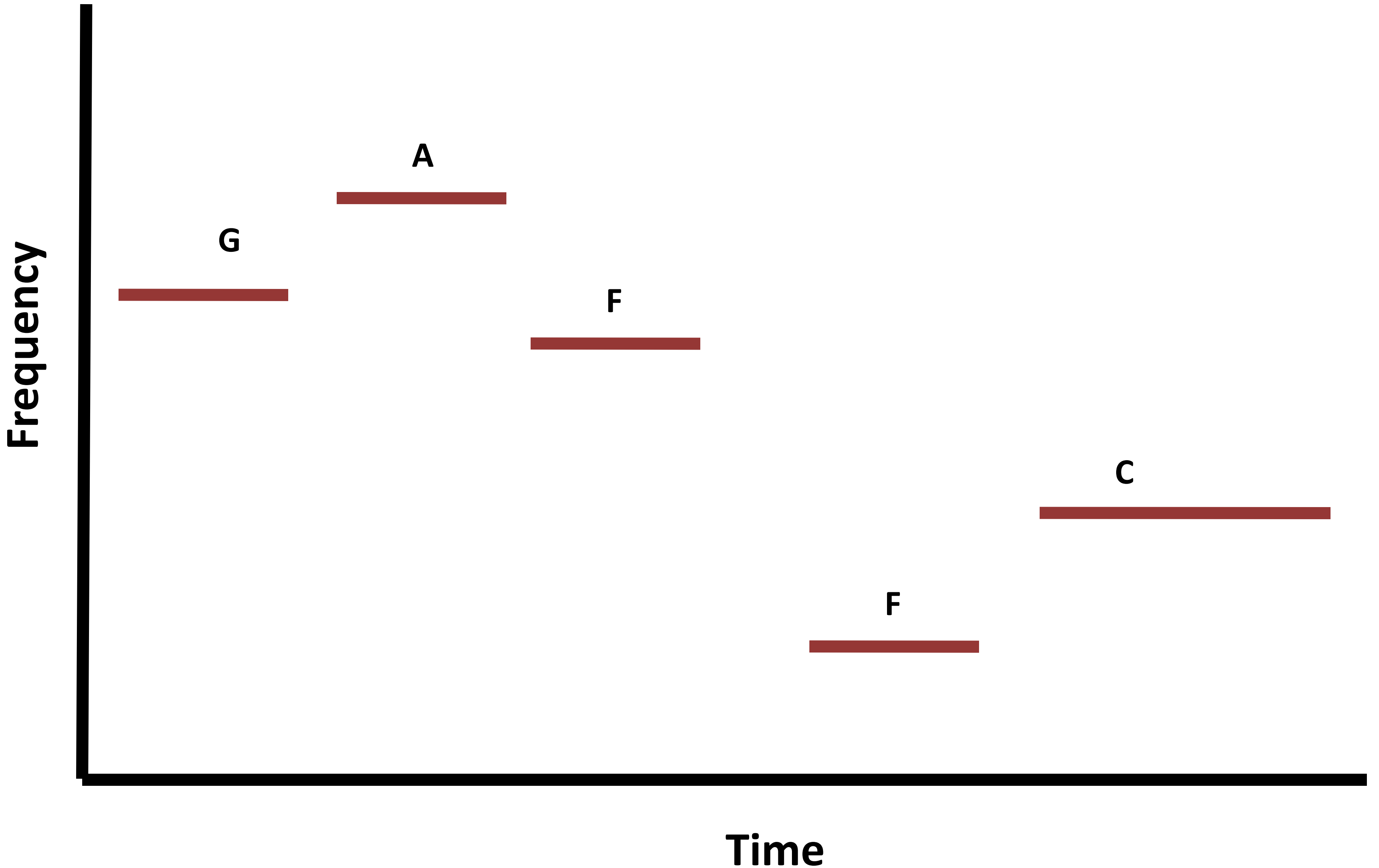

Boys
Girls
Frequency
Time


Frequency
Time


Frequency
Time


Frequency
Time


Frequency
Time



Frequency
G
A
F
F
C
Time

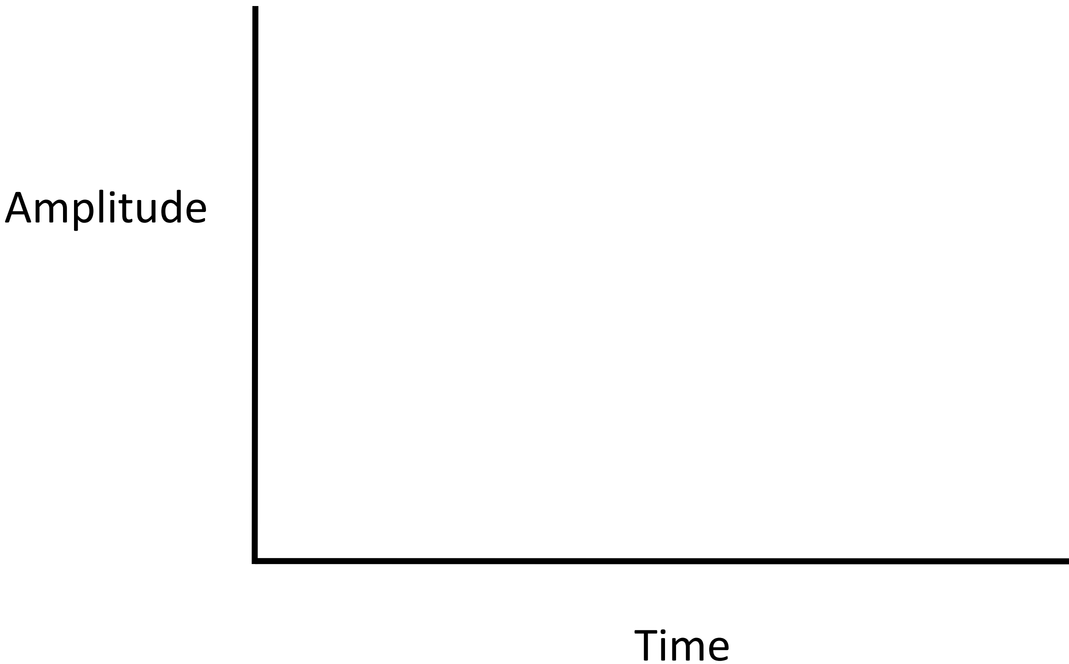
# Amplitude

- We often talk of the ‘loudness’ or ‘volume’ of a sound but the correct term for this is the **amplitude.**
- Sound, like all waves, is a way of getting energy from one place to another.
- The louder the sound, the more energy that is being shifted from one place to another.

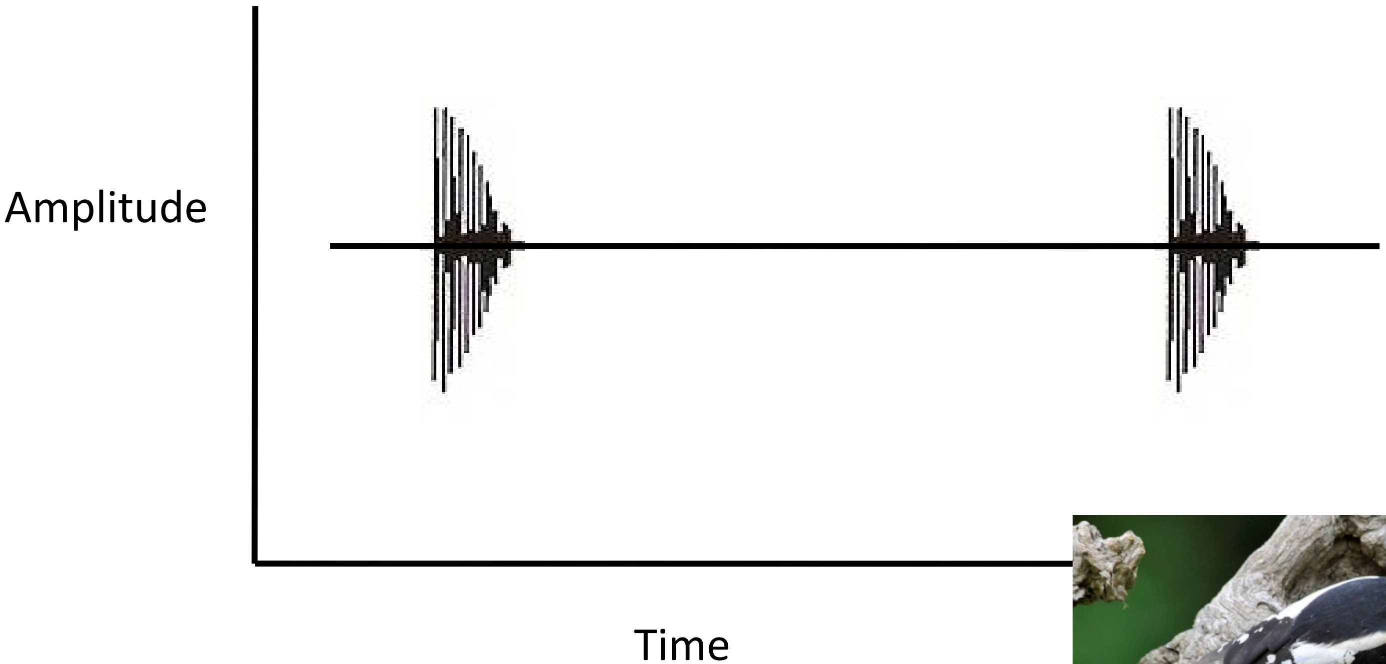
# Amplitude

- Although the vibrating particles of air do not move very far, the louder the sound, the further they vibrate (**NOT FASTER** –that is frequency!) from where they started.
- But they still don’t move along with the sound wave. They end up more or less where they started.
- The greater the amplitude, the louder the sound.

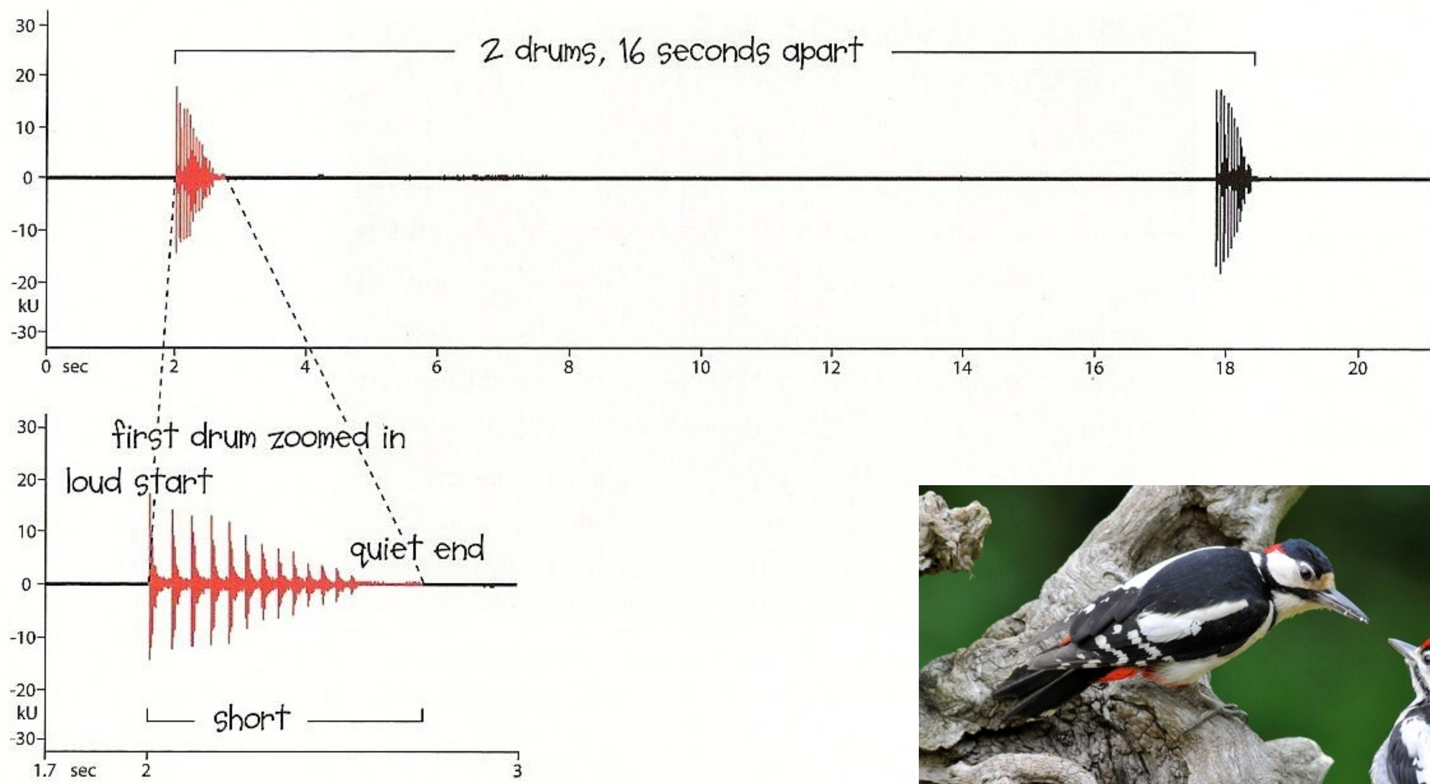
# A different graph can tell us how amplitude varies over time




# The Greater Spotted Woodpecker

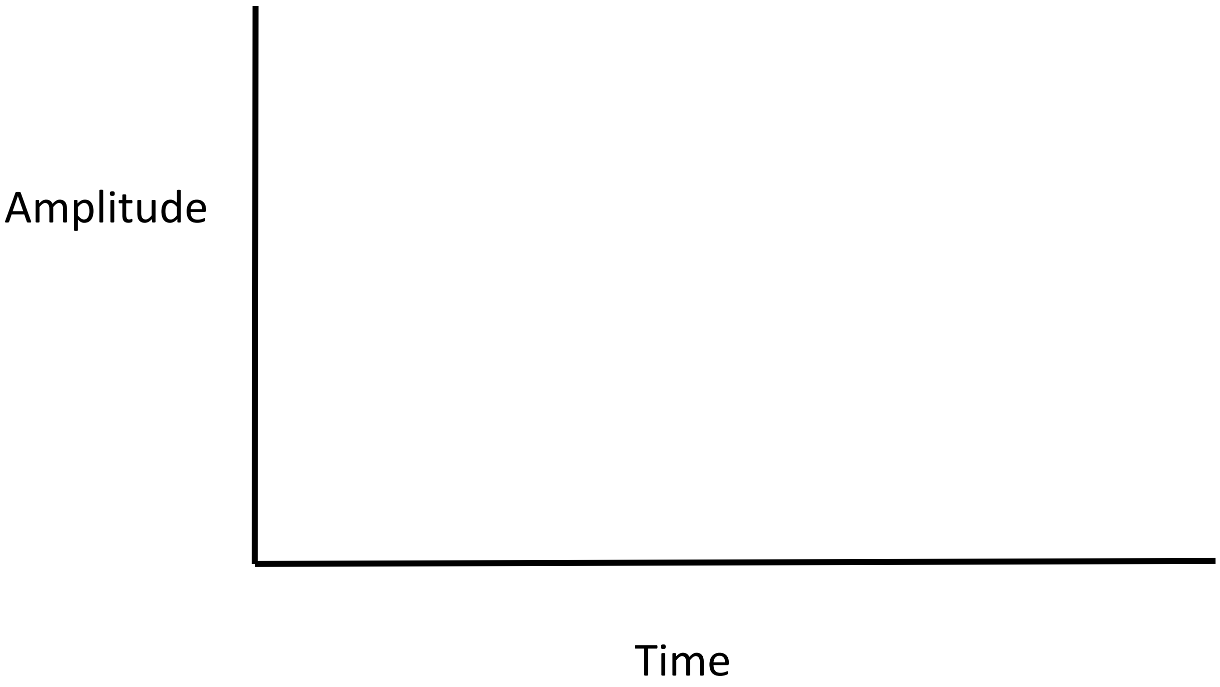



# The Greater Spotted Woodpecker

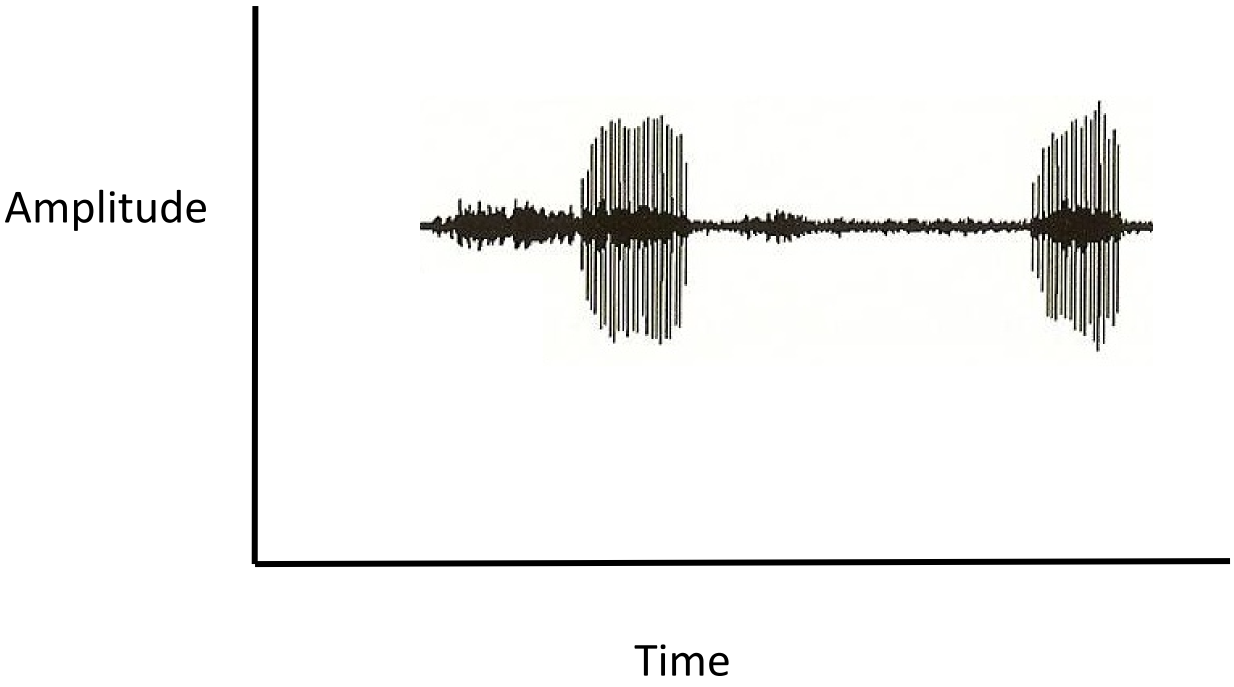



*Please note that in the sound clip, the time between the pecks has been shortened*

# The Lesser Spotted Woodpecker




# He may be 'lesser' but he is more consistent.

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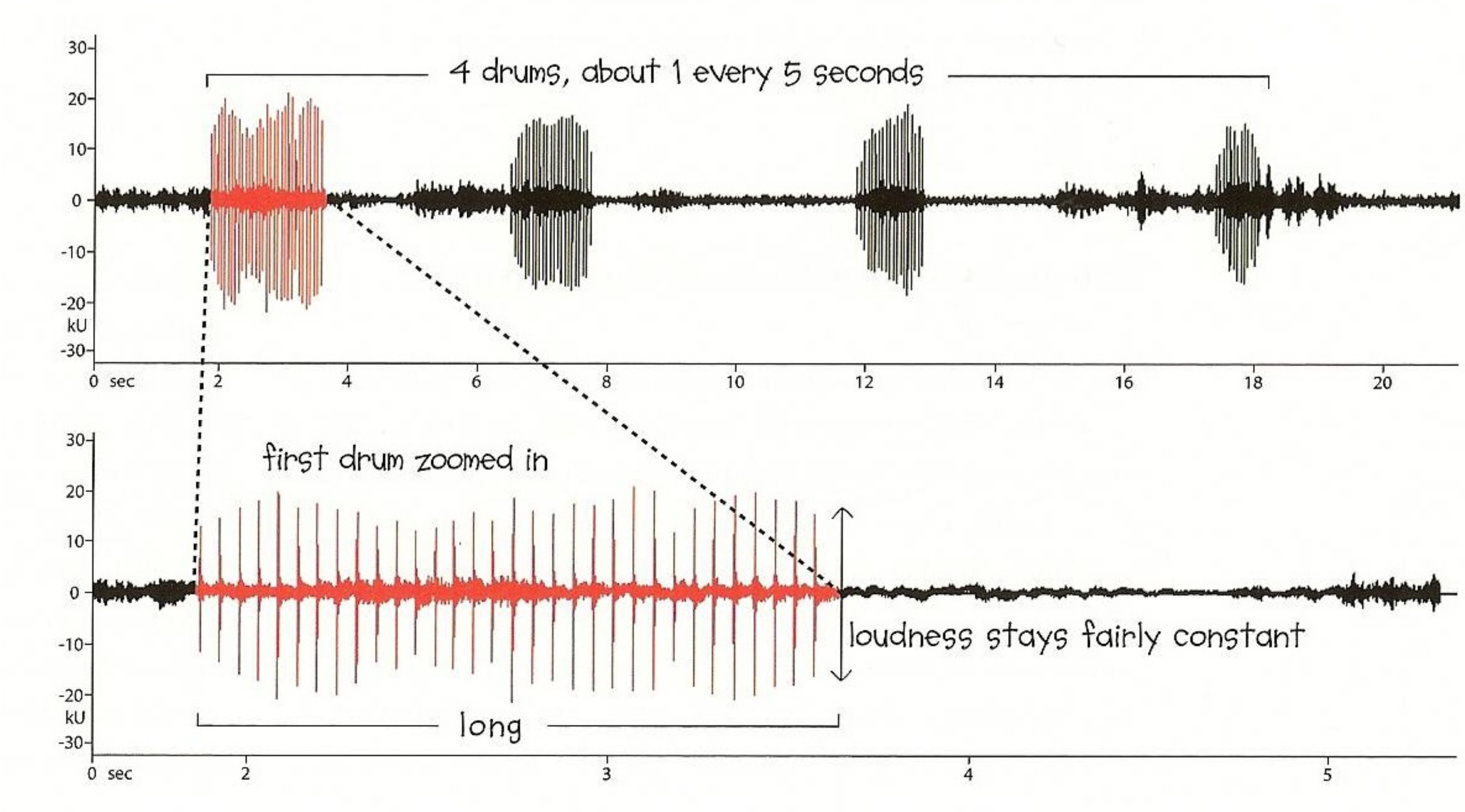
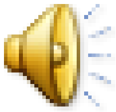


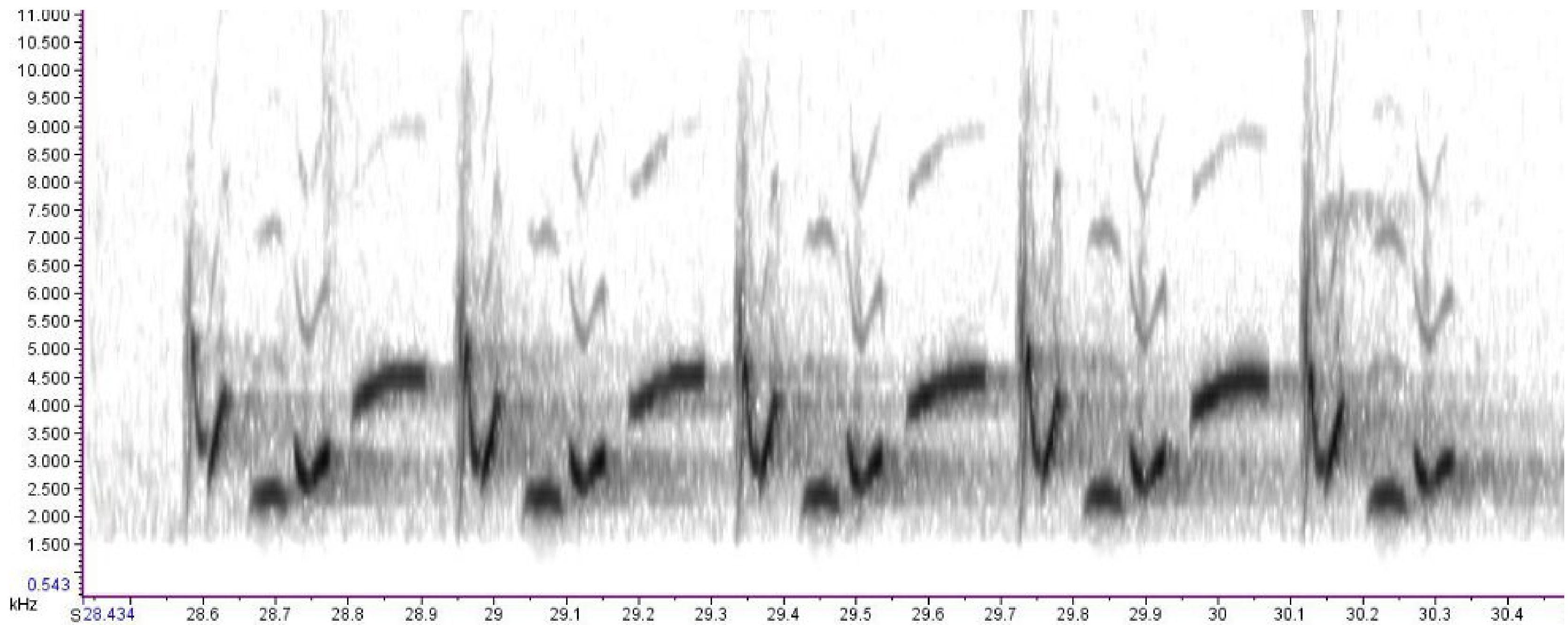



# Greater vs. Lesser

# EXTRA SLIDES

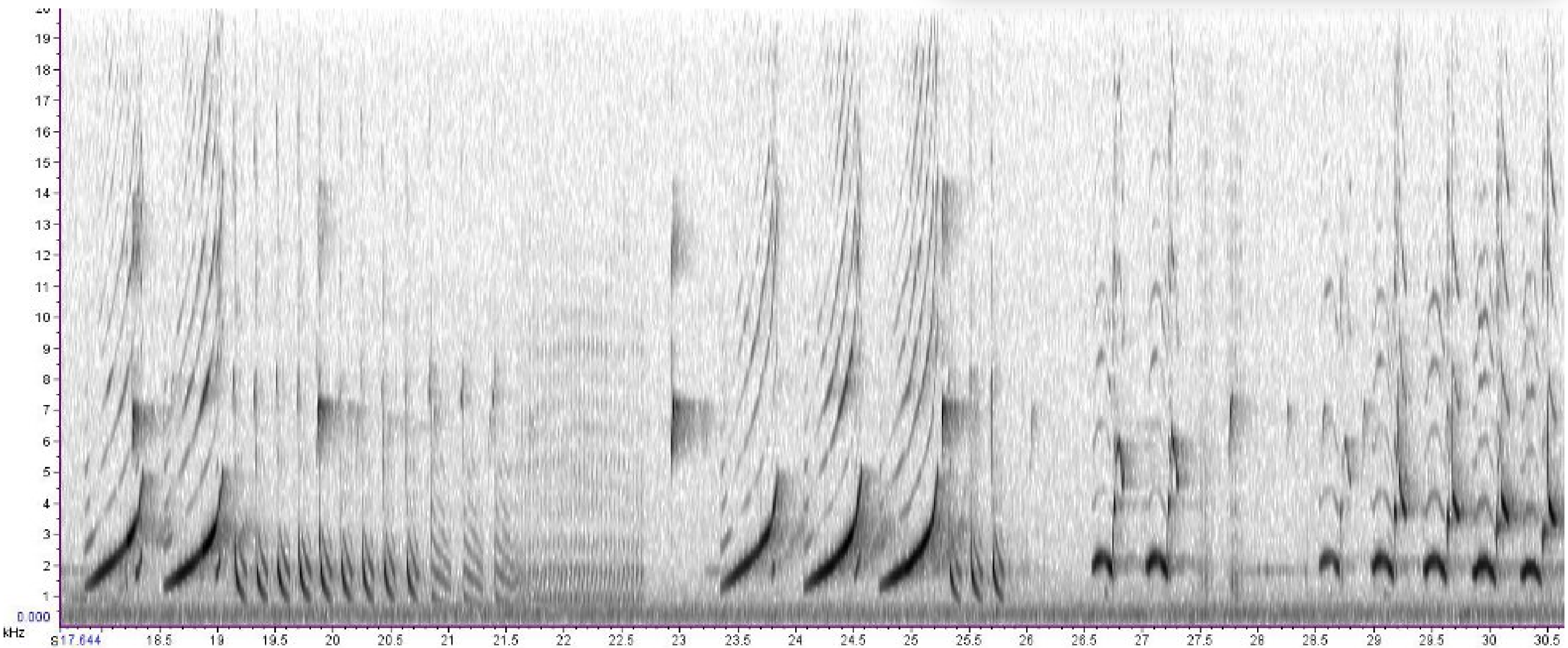
# Carolina Wren

A series of 3-4 note phrases.
Notes 3 & 4 fluctuate In pitch.



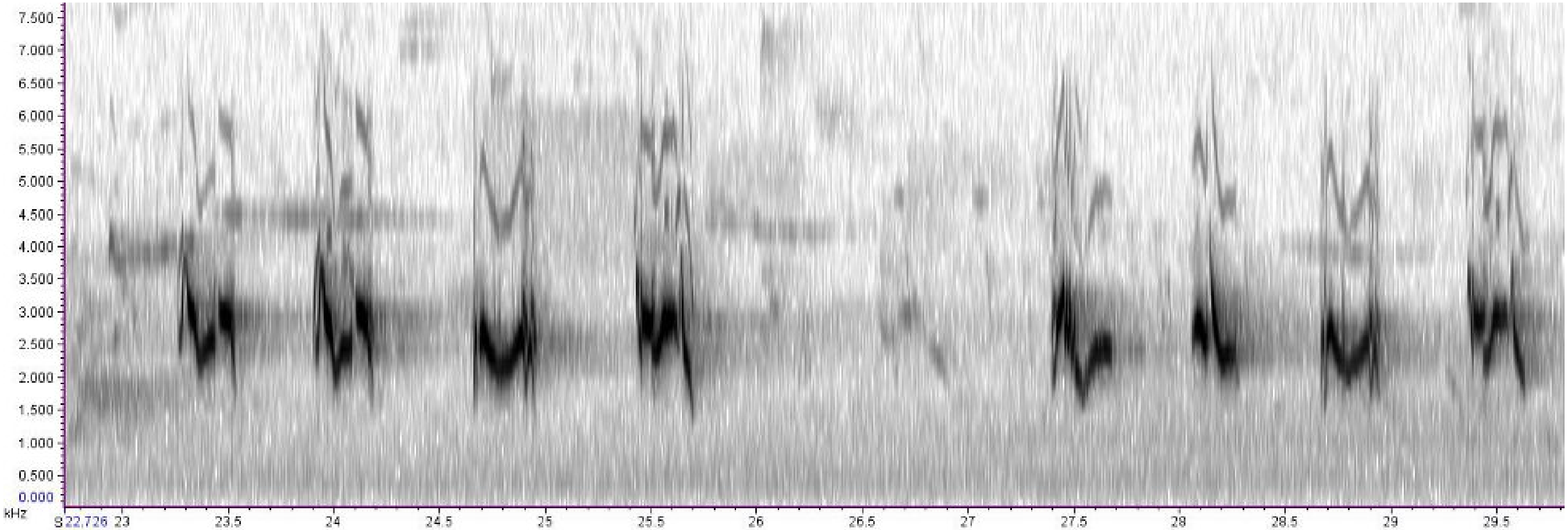
# Northern Cardinal

Variable song with series of slurred whistles,
followed by a series chrrr notes.
Pause length between phrases varies.



# American Robin

Repetitive series of the same note which fluctuates in pitch.
Note repeats 4x, followed by a pause.



# A more complex song: The common Rosefinch

- Try and have a go!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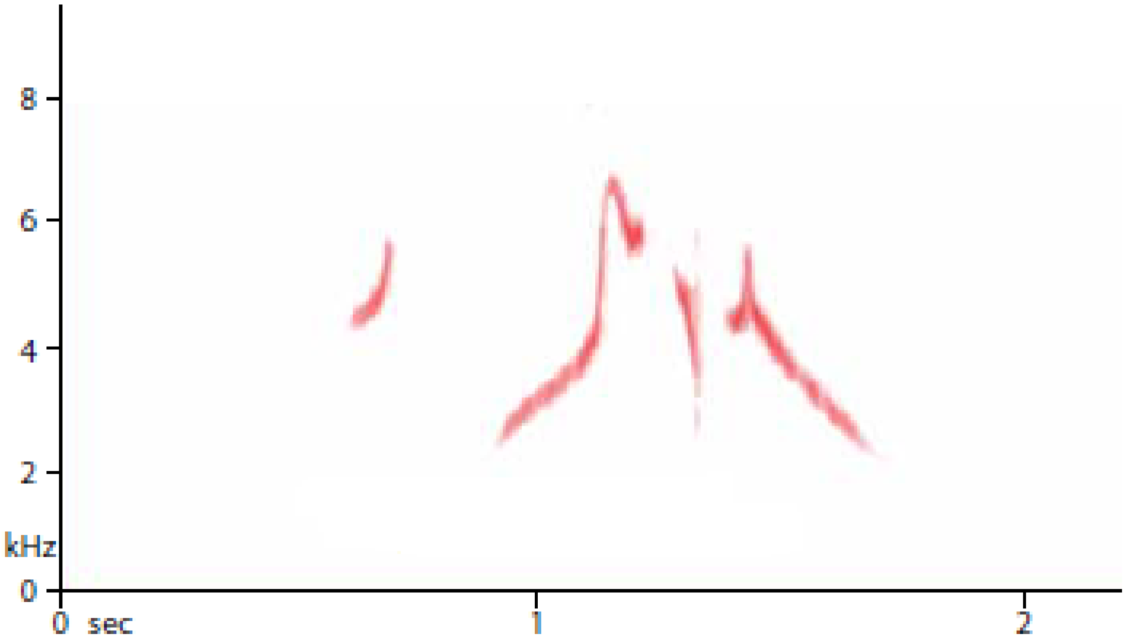
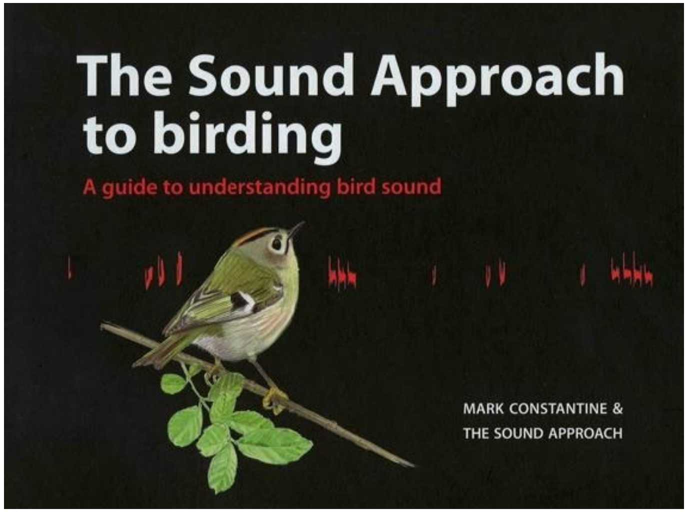
- Try and have a go!



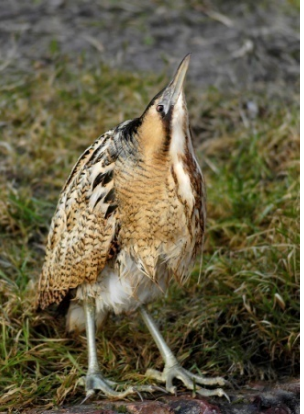

# An alternative, birding approach to teaching sound

James de Winter
birdsong@cambridgescience.co.uk



# The Human Hearing Range

- Most humans can hear sounds between about 20Hz and 20,000Hz (20kHz).
- As we get older, out ability to hear very high notes tends to reduce and so we may only hear up to 15kHz.
- Other animals can hear different  ranges, for example for dogs it is about 40Hz to 60,000Hz, mice 1000Hz to 70,000Hz and bats 20Hz to 120,000Hz.




# Birds span almost the full human hearing range

- Great Bittern (167Hz)
- Ural Owl (370Hz)
- Common Cuckoo (570Hz, 520Hz)
- Little Owl (1.2kHz)
- Common Redshank (2.33kHz)
- Common Sandpiper (4.8kHz)
- Goldcrest (7kHz)
- Lesser Whitethroat (11.7– 12.3kHz)
  - (the first few notes are the very high ones)



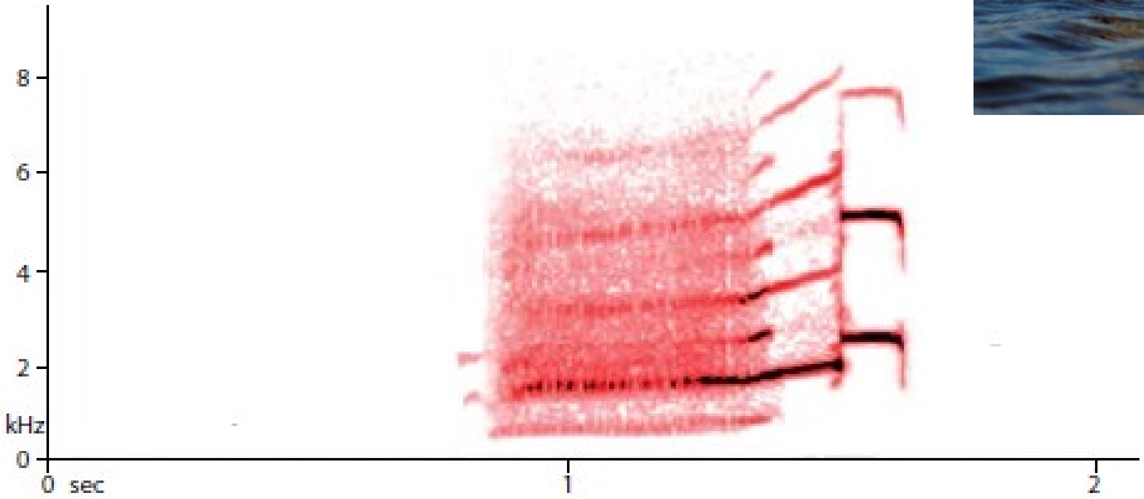

# Spectrograph Analysis

- **Black-capped Chickadee *(Poecile atricapillus)***

**Black-capped Chickadee, June 4, 2009, Scuppernong Spring Nature Trail- South Kettle Moraine State Forest, US-WI, Waukesha.**

# The closer you listen, the more complex it gets

The call of the Eurasian Curlew starts with a long noisy part and then has a shorter, higher pitched part



# Other phenomena: Doppler Shift I

- When something producing a constant frequency sound is moving towards or away from the listener, the pitch of the sound appears to change. This is called the Doppler shift.
- If the sound is moving towards you, the pitch appears to go up, if the sound is moving away then the pitch appears to go down.

# Other phenomena: Doppler Shift II

- This effect is noticeable with Police and Ambulance sirens.
- This happens with all waves, including light.
- This principle helps us to measure how fast the universe is expanding using what we call redshift. Stars are moving away from us so their light changes frequency (and so colour) and is a little bit redder than expected (red has the highest frequency on the spectrum).

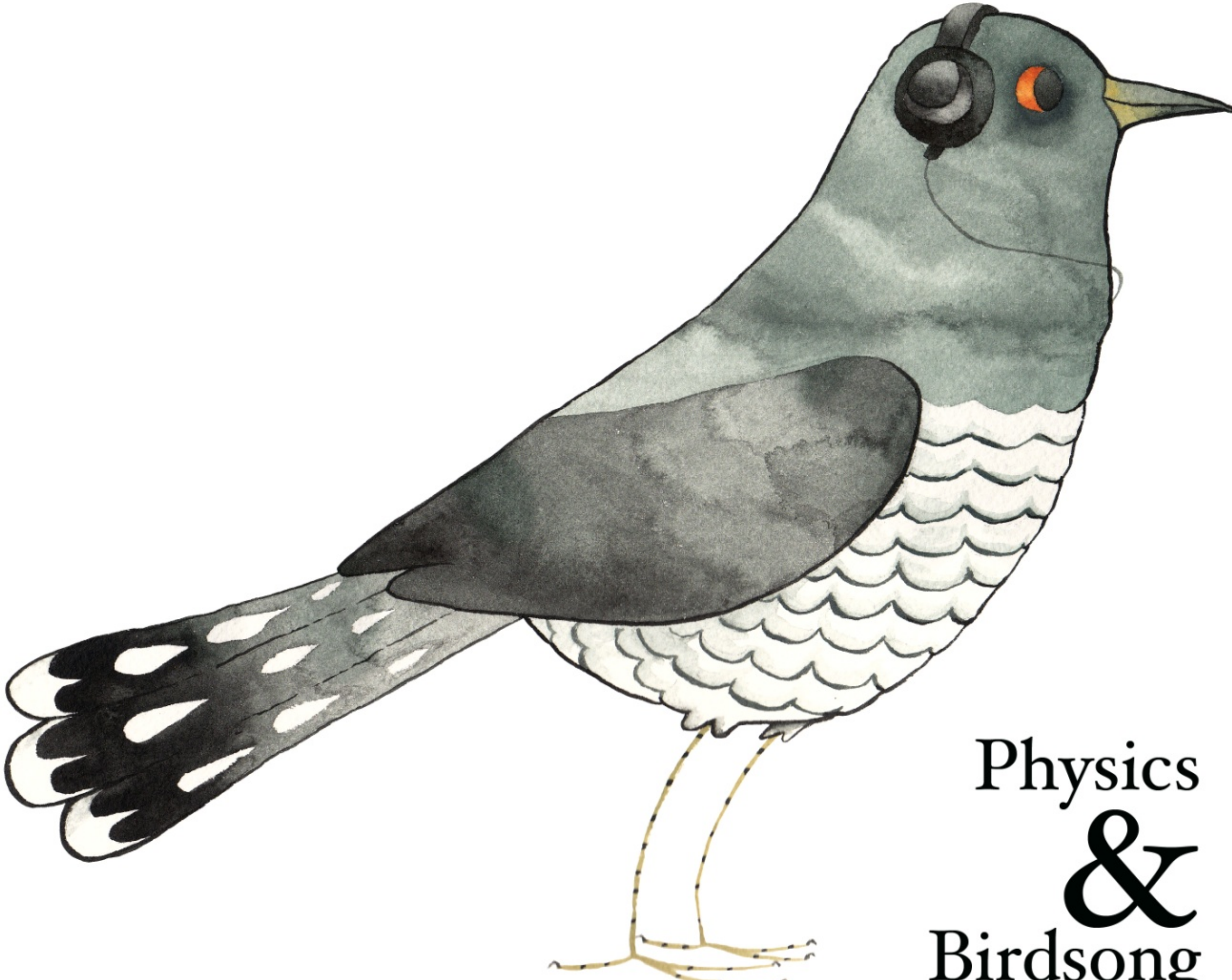
# Doppler shift and a Mute Swan

The swan flies quickly towards then away from us

# Cheerio

# Those involved

- James de Winter: ideas, writing, trialling and low level obsession with birdsong.
- The Sound Approach: Publish ***The Sound Approach to Birding*** book as well as others. Provided many of the images and all the sound files as well as encouragement.
- Matt Sewell: Painted the Cuckoo wearing headphones logo.



Physics & Birdsong

birdsong@cambridgescience.co.uk