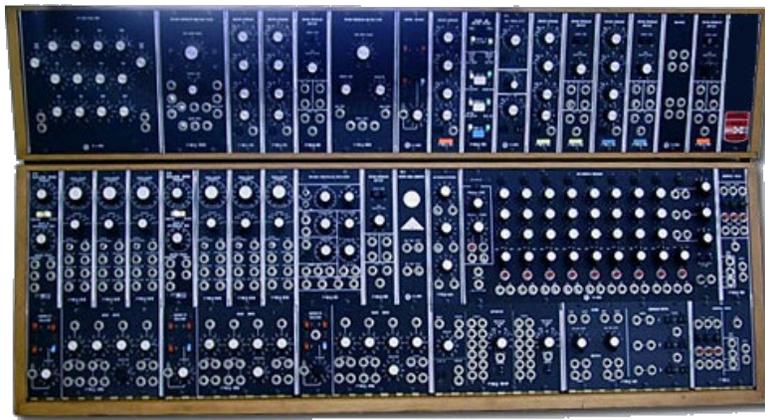# Module 5. Music Synthesizers

TuneScope is an extension of Snap! that facilitates creation of sound and music through coding. ToneScope combines SoundScope (introduced in the previous module) with Snap! TuneScope can be accessed at:

www.tunescope.org

Note: On a Macintosh, TuneScope must be accessed through either the Chrome or Fire Fox browsers. (TuneScope will not work properly in the Safari browser.)

Robert Moog developed the first commercially available music synthesizer. The Moog synthesizer was used to produce the album *Switched-On Bach*. This work became the second classical music album to sell more than a million copies.

The first music synthesizers were constructed using analog electronics rather than digital computers. However, it soon became possible to recreate these same effects using personal computers. Music synthesizers – regardless of whether they consist of dedicated electronic equipment or digital computers – recreate music using audio oscillators and filters.

This module provides an introduction to generation of sound and music using TuneScope. TuneScope code blocks provide the capability to generate tones through code. The addition of an audio frequency oscilloscope at the top of the Snap! screen is one of the most noticeable enhancements. The TuneScope display can be used to inspect and analyze acoustic waveforms.

TuneScope provides the capability for synthesizing tones and musical instruments. Music can be generated by a computer in two different ways:

1. through synthesized sound, and
2. through sampled sound.

These topics are discussed in the sections that follow.

## Topic 5.1 Synthesized Sounds – Generating a Tone

Computers can generate sounds digitally. Previous modules introduced the methods by which a computer can employ a sine function to generate a sine wave. When a digitally-generated sine wave is transmitted to a computer speaker, the resulting sound is perceived as a pure tone.

Pure tones are particularly useful because any regular (periodic) sound such as a musical note can be synthesized by combining a series of pure tones. This concept was introduced in the previous module, which introduced SoundScope. SoundScope can be used to adjust the frequency and amplitude of tones using manual controls.

Use of computer code to achieve the same outcome makes it possible to explore effects that go beyond the results possible with manually adjusted tones. To generate a tone and display the tone on the TuneScope oscilloscopic display, first select Snap! as an option from the drop-down *Mode* menu in the upper right-hand corner of TuneScope.
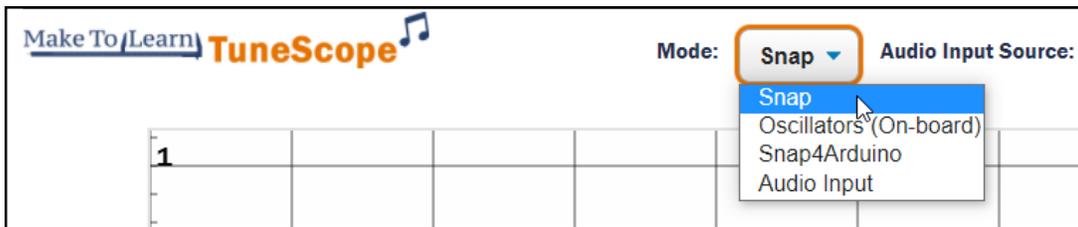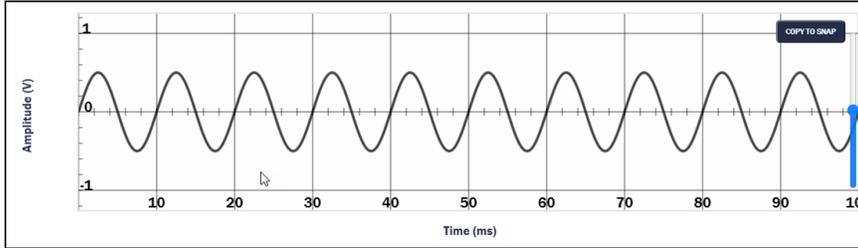

Then select *Oscillators* as an option from the *Audio Input Source* menu.
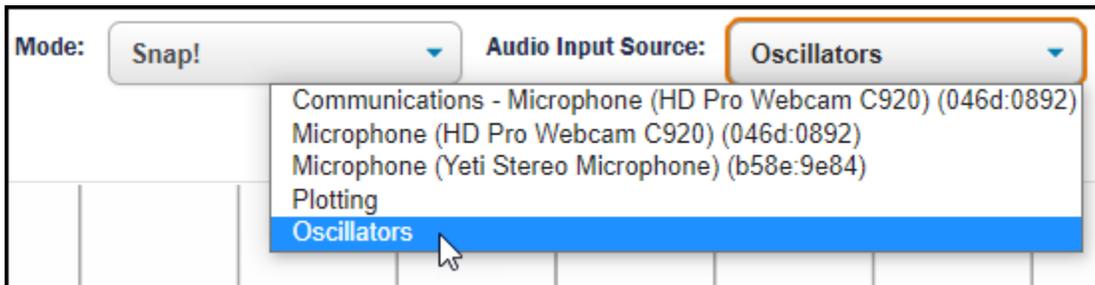
Once these display settings have been selected, use the **Tone Frequency _ Amplitude _** block to generate a tone and display its waveform on the TuneScope display.

2

The acoustic waveform will appear in the display once these blocks are executed.

Change the **Tone Number** input from green to red (by clicking the input) to turn off the tone.

**Exploration 5.1** Synthesized Sounds – Generating a Tone

Explore different frequency and amplitude settings. What effect does changing the frequency have on the tone? What effect does changing the amplitude (in the range from 0 to 1.0) have on the tone? (Be sure that the sound on your computer speakers is enabled.)

Topic 5.2 Synthesized Sounds – Frequency

The term *frequency* refers to how frequently an event occurs. A tone displayed on the TuneScope display reveals that there is a pattern that is repeated over and over again. Each repetition of the pattern is referred to as one *cycle*.

A tone for which the pattern repeats 100 times in one second is described as having a frequency of 100 *cycles per second*. In honor of the pioneering scientist, Heinrich Hertz, the term *Hertz* (abbreviated Hz) is also used as a term to describe the number of times per second that an event occurs. Frequency is correlated with the perceived *pitch* of a sound. As the frequency increases, the perceived pitch increases. Frequency is a physical phenomenon. Pitch is the perceptual correlate of frequency.

The default TuneScope display shows about 100 milliseconds (i.e., one-tenth of a second) of the waveform. Ten cycles of a tone with a frequency of 100 cycles per second will appear in 100 milliseconds. Counting the peaks of the cycles (as shown in the illustration below) is a good way to confirm that ten cycles of a 100 cycle per second tone will be displayed in 100 milliseconds.
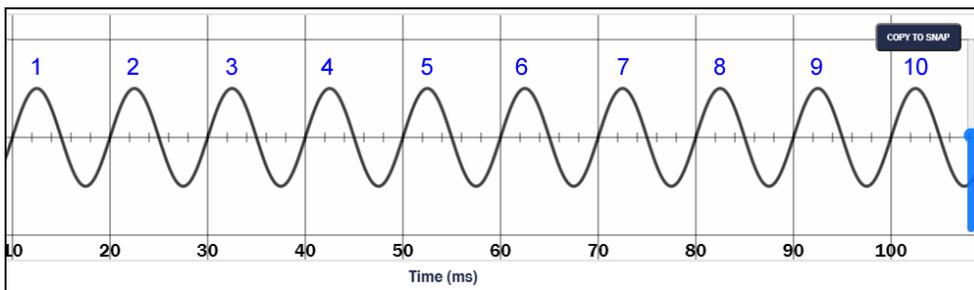
Since there are 1,000 milliseconds in one second, 100 cycles in one second is equal to 1 / 100 second (0.01 seconds). The duration of one cycle is known as the *period*. Therefore a 100 cycle per second tone has a period of 1 / 100 second. Not all sounds have a discernable pattern that repeats. Sounds that have a repeating period are known as *periodic sounds*. Sounds that do not have a repeating period are known as *aperiodic sounds*.

Exploration 5.2 Synthesized Sounds – Frequency

Explore tones of different frequencies. When the frequency of a tone is doubled, what is the effect on the perceived pitch? What is the lowest frequency tone that you can hear? What is the highest frequency sound that you can hear?

Topic 5.3 Synthesized Sounds – Intensity

The height of the waveform is known as its amplitude. In the illustration below, the amplitude of the highest positive peak is + 0.5 and the amplitude of the lowest negative peak is – 0.5.
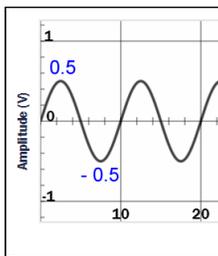
The maximum amplitude of a waveform that can be displayed without distortion in TuneScope is 1.0 for the highest positive peak and – 1.0 for the lowest negative peak. If the waveform exceeds those values, it will be distorted.

When the tone is sent to the computer speaker, the high peak of the waveform corresponds to the farthest forward excursion of the speaker cone. The low peak of the waveform on the display corresponds to the farthest backward excursion of the speaker cone. If there are 100 cycles of the acoustic waveform in one second, the speaker cone moves forward and backward 100 times in that second. Thus, the amplitude of the waveform corresponds to *how far* the speaker cone moves while the frequency of the waveform corresponds to *how many times* the speaker cone moves back and forth in one second. When the speaker cone moves a greater distance, it displaces more air, resulting in a more intense sound. The intensity of a sound is measured in *decibels*.

Intensity is correlated with the perceived *loudness* of a sound. As the intensity increases, the perceived loudness increases. Intensity is a physical phenomenon. Loudness is the perceptual correlate of intensity.

**Exploration 5.3** Synthesized Sounds – Intensity

Explore synthesized tones with different amplitudes. When the amplitude of a tone is doubled, what is the effect on the perceived loudness? What is the lowest amplitude tone that you can hear? When the amplitude of a tone exceeds 1.0 on the TuneScope display what is the effect on the perceived quality of the sound generated?

Topic 5.4 Synthesized Sounds – Complex Tones

Most naturally occurring periodic sounds are not pure tones. Instead, naturally occurring periodic sounds are typically composed of several pure tones with different frequencies. In the illustration below, two pure tones have been generated in TuneScope: a 100 Hz tone and a 200 Hz tone.


The TuneScope display that results from combining a 100 Hz tone and a 200 Hz tone looks like the illustration below.
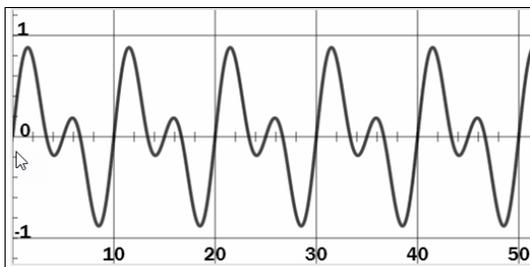

A sound that is composed of two or more pure tones is known as a *complex tone*. A complex waveform has a quality that is perceived as richer than a pure tone. Most musical instruments generate sounds that are complex waveforms.

Music synthesizers recreate these musical tones by combining pure tones of different frequencies and amplitudes. A series of tones can be created in *TuneScope* by snapping blocks together in the same manner as the two tones in the previous example.

A **For** loop can be used to generate a series of tones to create a complex waveform. A computer loop executes an action (in this case, turning on a tone) over and over. In this example, the loop is repeated three times. During the first iteration of the loop, the value of the variable "*i*" is "1"; during the second iteration, the value of the variable "*i*" is "2"; during the third iteration, the value of the variable is "3".
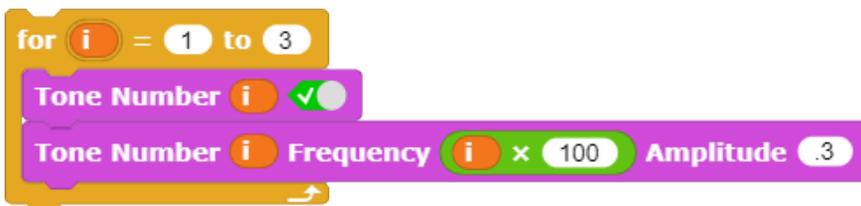
The effect is the same as creating the following three sets of commands manually. In this case, Tone 1 has a frequency of 100 Hz, Tone 2 has a frequency of 200 Hz, and Tone 3 has a frequency of 300 Hz.
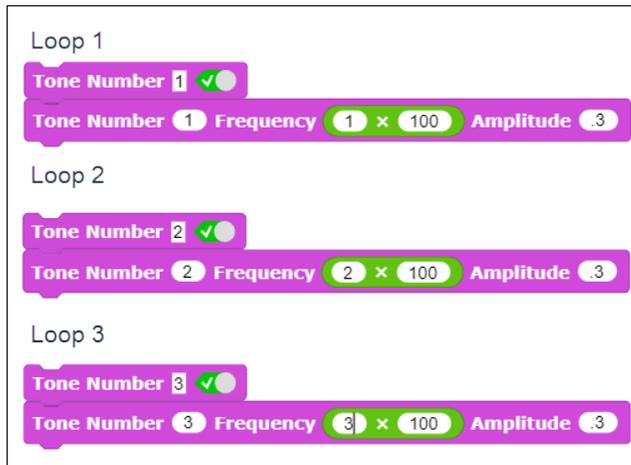
A loop makes it possible to experiment with complex waveforms in a fraction of the time that it would have taken to create these waveforms manually by snapping commands together one at a time.

A loop also can be used to quickly turn off a series of tones.

In previous sections, the acoustic characteristics of frequency and intensity have been explored. The perceptual correlate of complexity in a waveform is *timbre*. The perceived quality of a sound – known as its timbre – is affected by the complexity of the waveform.

**Exploration 5.4 Synthesized Sounds – Complex Tones**

Explore the effect of combining several tones to create a complex waveform. How does addition of several pure tones affect the perceived quality of the sound generated?
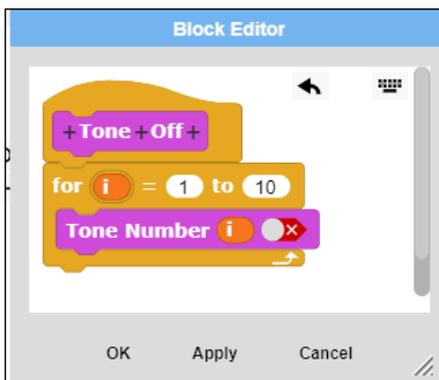
Topic 5.5 Custom Code Blocks

Once you are satisfied with the effect of a sequence of code blocks that you have created, you can create a custom code block to execute that sequence. Click the plus sign "+" in the corner of the *Command Palette* to make a custom block.
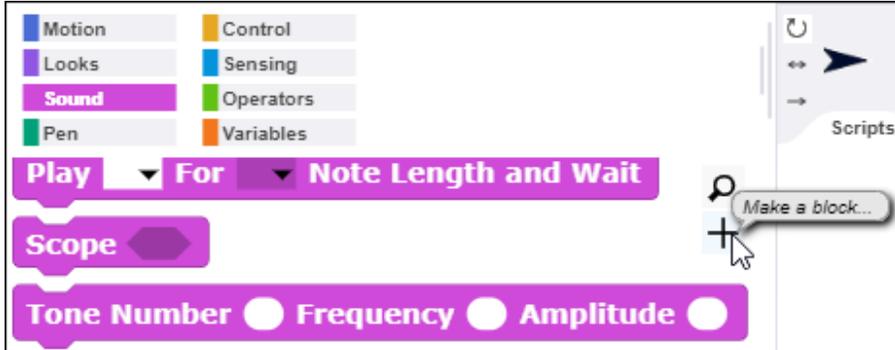
Then assign a name to the new block (*Tone Off* in this example) in the dialog box that appears.
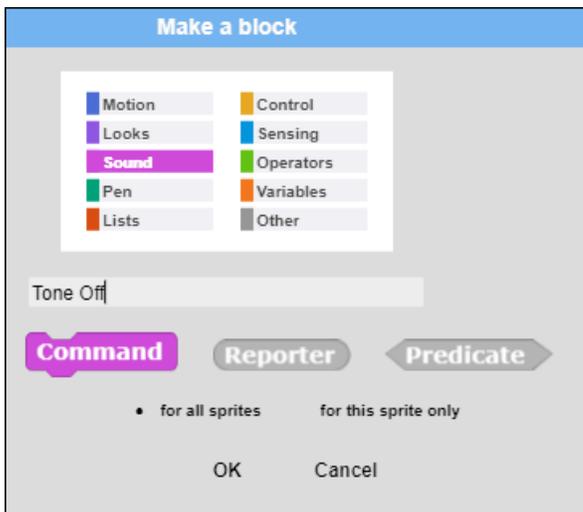
Click OK to advance to the next dialog box. A *Code Block Editor* will appear. Drag the blocks to turn the tones off into the *Block Editor*.

Then click *OK* to complete the process of creating a custom code block. The newly created code block will appear at the bottom of the code block area in the command palette.

After dragging the new custom code block into the script area, you can execute the sequence of code blocks by clicking the custom block – in this instance, the newly defined **Tone Off** code block.

**Exploration 7.5** Custom Code Blocks

Create a custom code block that generates a complex waveform.

Topic 5.6 Sampled Sounds – Duration

Duration is one other parameter of a sound that is important in music. The duration of a tone can be set using a **Wait** code block to establish the length of time that the tone plays before it is turned off.


This capability can be used to create a series of pulses by rapidly turning a tone on and off.
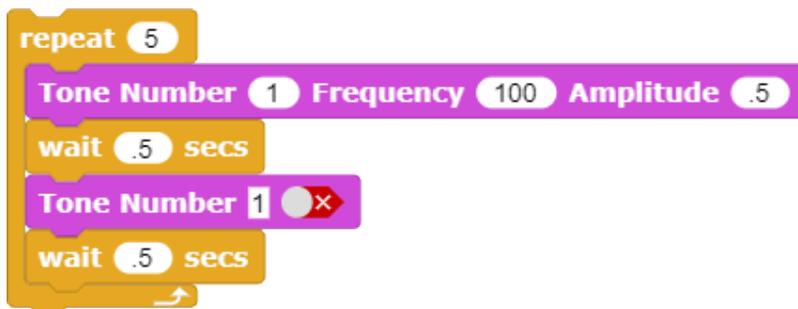
An input to a custom code block can be created by clicking the plus ("+") sign to the right of the name of the code block in the code block editor. A dialog box will then appear that enables an input to the code block to be created. In this illustration, the input *Times* will be used to specify the number of times that the pulse will occur.
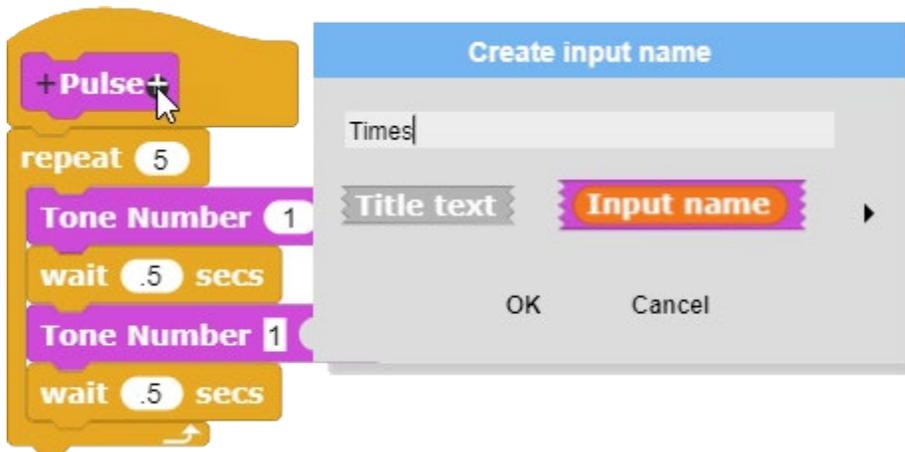
The orange oval representing the *Times* input is then dragged into the input slot for the **Repeat** block.
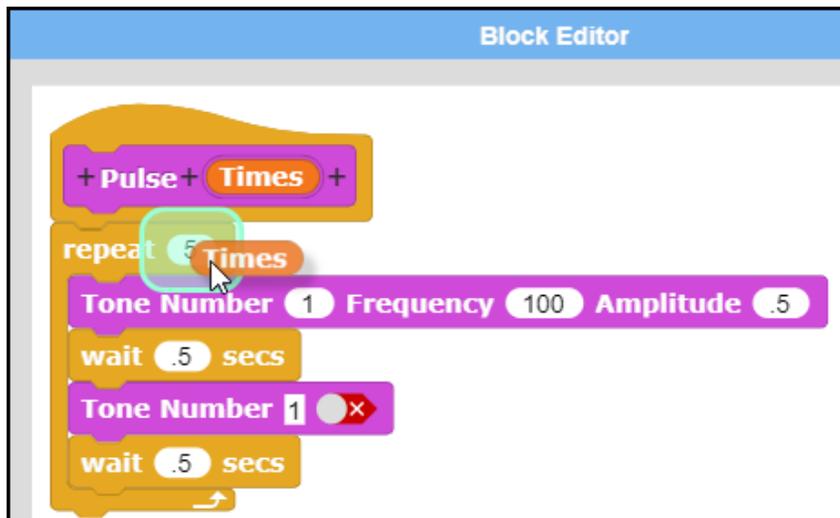
The input to the custom code block will then determine the number of times that the tone will pulse on and off.

This method can be extended for complex tones, and can even be used to combine several complex tones. This method will be extended to create notes for musical instruments and musical chords in the next module.
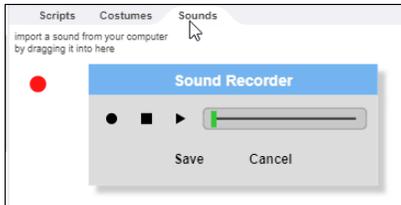
Exploration 5.6 Sampled Sounds - Duration

Create a custom code block with an input that pulses a complex waveform.

Topic 5.7 Sampled Sounds – Recording Sounds

Synthesized sounds, described in preceding sections, are one method of generating sounds with a computer. The other method of producing sounds with a computer consists of capturing and playing back natural occurring sounds. The computer's microphone can be used to capture a sample of a naturally occurring sound.

The sound recorder in TuneScope is accessed through the *Sounds* tab to the right of the *Scripts* tab. (Note: on a Macintosh, you will be asked to give permission to access the computer's microphone the first time the sound recording capability is accessed.)

Once a sound has been recorded, it can be assigned any name that is appropriate. In this instance, a ringing sound was created by tapping a fork on a water glass.
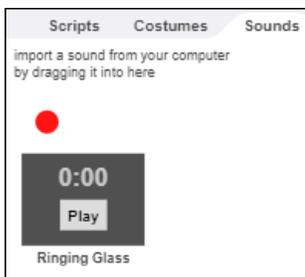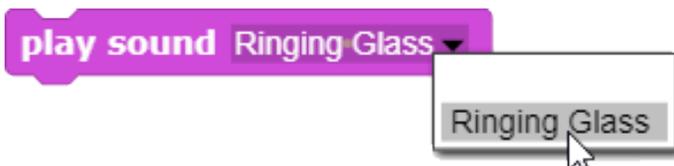

Exploration 5.7 Sampled Sounds – Recording Sounds

Record several sounds. Assign a meaningful name to each sound sample that has been captured.

Topic 5.8 Sampled Sounds – Playing Recorded Sounds

Once a sound has been recorded and assigned a name, it can be accessed through a drop-down menu in the **Play Sound** code block.

Once a sound has been selected through the drop-down menu, it can then be played by clicking the **Play Sound** block.

**Exploration 5.8** Sampled Sounds – Playing Recorded Sounds

Use the **Play Sound** code block to play back recorded sounds. What happens if you play several sounds one after the other by snapping several Play blocks together? What is the difference between the **Play Sound** code block and the **Play Sound until Done** code block?

Topic 5.9 Designing a Sound Pad on the Computer Keyboard

Professional musicians use specialized hardware that can be used to create musical loops (i.e., a repeating musical pattern) and sound effects. A sound pad is one type of music controller that is popular with musicians and audio engineers. Rows of keys control sound effects and sound loops. Pressing a key triggers a specific sound or musical loop.

Any sound or code block created in TuneScope can be assigned to a key on the computer keyboard. The **When Key __ Pressed** code block is used to assign a sound or code block to a key on the computer keyboard.
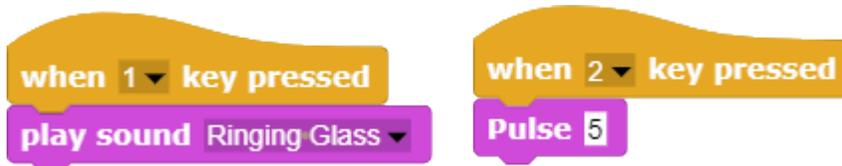
Once a sound or code block has been assigned to a key on the computer keyboard, pressing the key triggers the sound effect or pre-recorded sequence.

Exploration 5.9 Designing a Sound Pad on the Computer Keyboard

Assign a series of a half-dozen to a dozen synthesized and sampled sounds to keys on the computer keyboard. Then use a smart phone to record a video performance in which a dramatic reading of a story or poem is accompanied by sound effects.