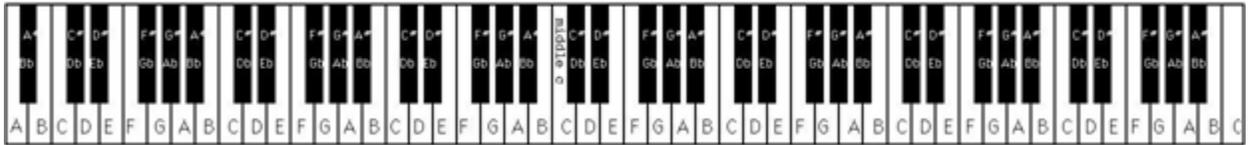


8. Musical Scales

Glen Bull, Jo Watts, Rachel Gibson, and Luke Dahl

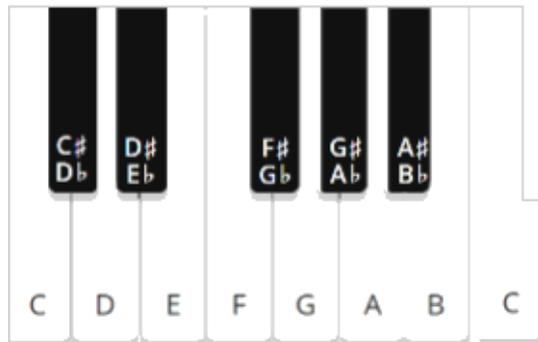
The term musical scale refers to a sequence of notes ordered by frequency or pitch. Many different musical scales have been developed throughout history. The Western chromatic musical scale consists of twelve notes. Other scales have been developed that employ different numbers of notes.



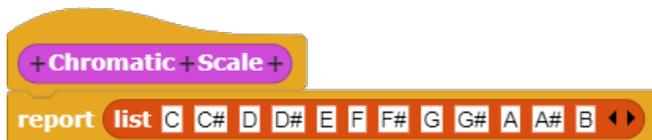
The overwhelming majority of popular music today is composed using groups of notes drawn from within the notes of the chromatic scale. The keys of today’s pianos are tuned using this scale.

Topic 8.1 The Twelve-Note Chromatic Scale

The concept of an octave was introduced in Module 6 (*Combining Art and Music*). An octave is a span of notes on the piano keyboard that begins with one note (such as the note “C” in the illustration below) and ends in the same note.



A custom **Chromatic Scale** code block reports the twelve notes of the chromatic scale.



The **Chromatic Scale** block can be used to construct major and minor scales that are subsets of the chromatic scale

Exploration 8.1 The Twelve-Note Western Chromatic Scale

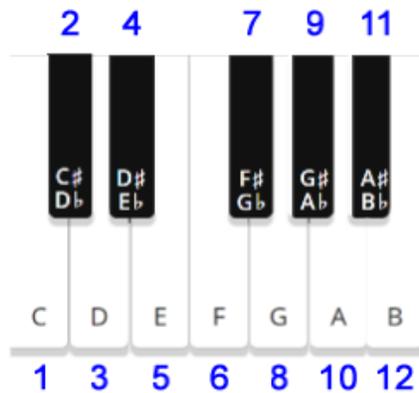
Create a custom code block that uses the **Chromatic Scale** code block described in this section as an input to play the notes of the scale in order. Modify the code block so that it plays the notes of the scale in order beginning and ending with the note “E”.

Topic 8.2 Major Scales

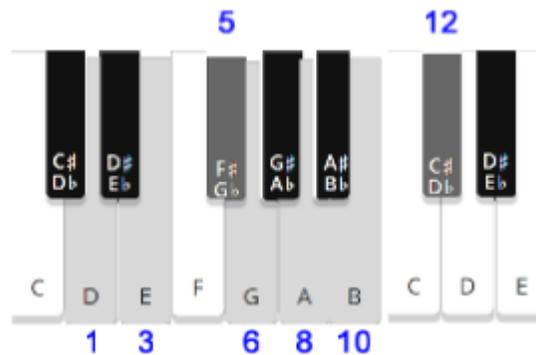
Many other scales have been formed that are subsets of the full twelve notes of the chromatic scale. In a previous module (*Combining Art and Music*), musical intervals of 4, 5, 7, and 9 were found to be generally perceived as harmonious when the two notes with that degree of separation were played together. For that reason, these intervals were used to construct harmonious motifs. The same strategy underlies construction of seven-note scales known as major scales. These scales are constructed with intervals perceived as harmonious – intervals of 4, 5, 7, and 9 – with additional intervals included to complete a seven-note scale.

Note	C	C#	D	D#	E	F	F#	G	G#	A	A#	B
Interval		1	2	3	4	5	6	7	8	9	10	11
Ratio					5:4	4:3		3:2		5:3		
Harmonious					Yes	Yes		Yes		Yes		

There were a number of competing approaches to scales in historic times, and the corresponding representation of notes on keyboards instruments. Over time the chromatic scale became the widely adopted system in traditional Western music. Within the chromatic scale, the C Major scale is the only one that has no sharps or flats. The white keys were consequently associated with this scale.



There are twelve major scales, one for each note in the chromatic scale. The notes for each major scale are always drawn from the same relative position in the chromatic scale. For example, the notes that form the D Major scale are drawn from the same relative positions of the chromatic scale. This scale consists of the notes numbered 1, 3, 5, 6, 8, 10, 12 (beginning with D) in the illustration below.



Using the same pattern of notes means that while the *absolute pitch* shifts, the relative intervals of one note to another within a scale remain the same. This makes it easy for musicians to transpose tunes from one scale to another, and facilitates musical exploration and invention. This regularity also facilitates creation of a custom code block that reports the seven notes in any major scale. For example, the notes of the C Major scale in the fourth octave are shown in the illustration below.



For those who are interested, details of how the **Major Scale** code block is constructed are provided in the appendix of this module

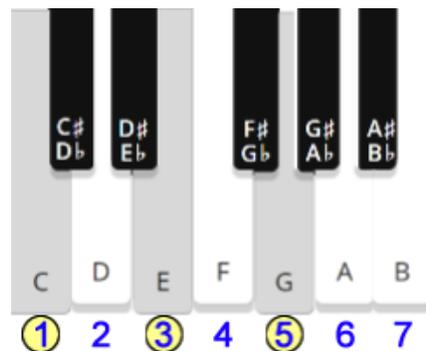
Much of the music in medieval times was designed to create music that sounds harmonious (i.e., heavenly). However, dissonance is also an important tool in composition of music. The blues, for example, make use of dissonance. The *minor scales* are perceived as more dissonant than the major scales. Minor scales are formed from the first, third, fourth, sixth, eighth, ninth, and eleventh notes of the chromatic scale.

Exploration 8.2 Major Scales

Create a custom code block that plays the first, third, and fifth note of a major scale. For example, in the C Major scale, the notes C, E, and G would be played. Try playing three note sequences from several scales one after the other; for example, C, E, and G followed by F, A, and C followed by G, B, and D.

Topic 8.3 Notes within Scales

The first, third, and fifth notes within any major or minor musical scale sound particularly harmonious when played in combination with one another. For example, C, E, and G in the C Major scale sound harmonious when played in combination with one another.



The **Note # in Major Scale** block reports the note associated with any position in a major scale. For example, E4 is the third note in the C major scale.



This block can be used as an input to the **Play Note and Wait** block.



Musicians also refer to musical intervals within a scale by name. These names are assigned with reference to the position of notes within the major and minor scales. A *major second* refers to the interval between the first and second notes in a major scale, a *major third* refers to the interval between the first and third notes in a major scale, etc.

Names of Musical Intervals			
<i>Note</i>	<i>Number</i>	<i>Name</i>	<i>Ratio</i>
C	1		
D	2	Major 2nd	
E	3	Major 3rd	5:4
F	4	Perfect 4th	4:3
G	5	Perfect 5th	3:2
A	6	Major 6th	5:3
B	7	Major 7th	

The two intervals with the lowest whole-number ratios (4:3 and 3:2) in the scale are known as a *perfect fourth* and a *perfect fifth* respectively. These are designated as perfect because they are judged to sound the most harmonious.

Exploration 8.3 Musical Intervals within a Scale

Create a custom block that randomly selects notes from different positions in a major scale. Play several different combinations of notes and judge which sequences sound best to you.

8.4 Musical Measures

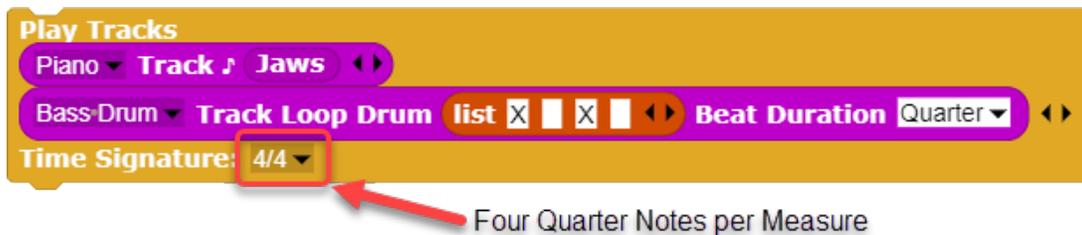
The concept of measures was discussed in the previous module (*Rhythms*). A measure in music is a unit that holds a specified number of beats played at a specified tempo. Notes within a measure are placed between vertical bars in music notation.



The **Measure** block is used to group sequences of notes that fall within a measure.



The notes in 4/4 time must add up to one whole note per measure.



Any combination of durations that add up to a whole note satisfies the requirements for a measure in 4/4 time.

Durations that Add Up to a Whole Note								
Number	Notes							
1	Whole							
2	Half	Half						
4	Quarter	Quarter	Quarter	Quarter				
8	Eighth	Eighth	Eighth	Eighth	Eighth	Eighth	Eighth	Eighth

The **Beats in Measure** block reports the number of beats associated with the notes currently in a measure. For example, the notes C4 (half a beat) and E4 (a quarter beat) add up to a total of 3 beats.

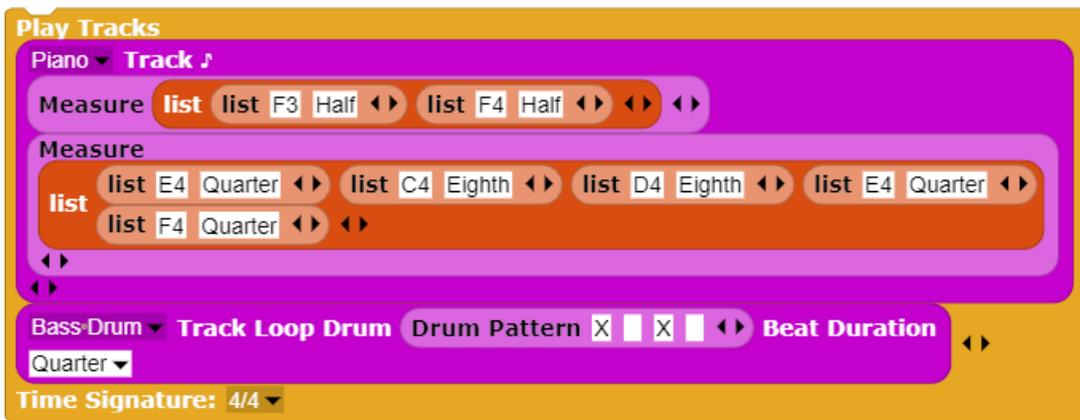


Since there are 4 beats per measure in 4 / 4 time, one more beat would be needed to complete the measure. The duration of the second note, E4, could be increased from a quarter note to a half note to accomplish this. Alternatively, a third note that is a quarter note in duration could be added to the measure.

Completed measures are assembled into instrumental tracks. The example below is a piano track. Note that each measure in this track adds up to a whole note.



The **Play Tracks** block was introduced in the previous module (*Rhythm*). The example below consists of a piano track combined with a drum track.



Topic 8.5 Music Visualization

TuneScope music blocks lend themselves to creation of music visualizations. Many different ways of visualizing music have been developed. Light shows often use color to represent different elements of the musical scale. Visualizations could be created that highlight different major or minor scales. In Snap! / TuneScope, many types of visualizations can be constructed using a separate sprite to represent each note. In Snap!, clones provide a way to create multiple instances of a sprite. A clone of a sprite can be created by right-clicking the sprite icon in the sprite corral below the stage.



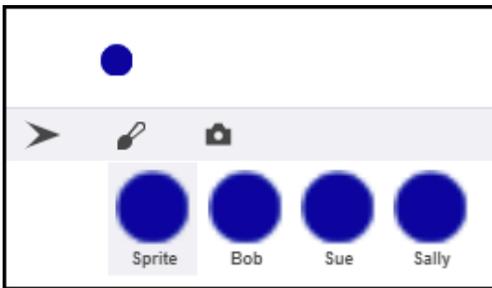
Two types of clones can be created with a script. Temporary clones are ones that disappear after they are no longer needed. For example, a shower of shooting stars might streak across the sky and

disappear after they burn up. A permanent clone is one that is permanent, like a regular sprite, but shares attributes of its template.

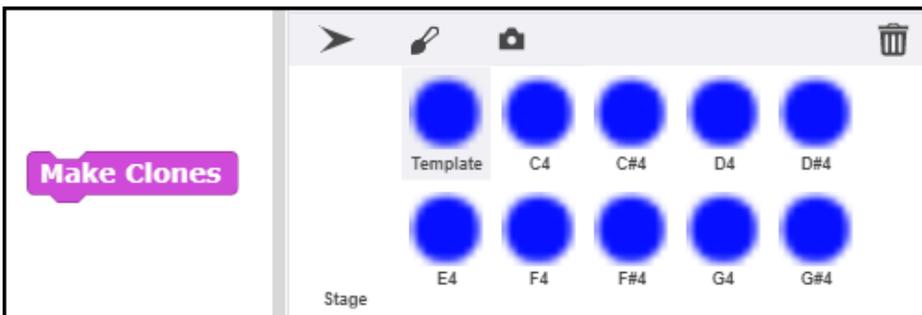
The following script creates a permanent clone for each item in a list of names: “Bob, Sue, and Sally”. The default state of a new program-generated clone is “temporary”; the script sets the *temporary* status to false, making the clone permanent. It also assigns each clone with a name corresponding to an item in the *List of Names* variable.



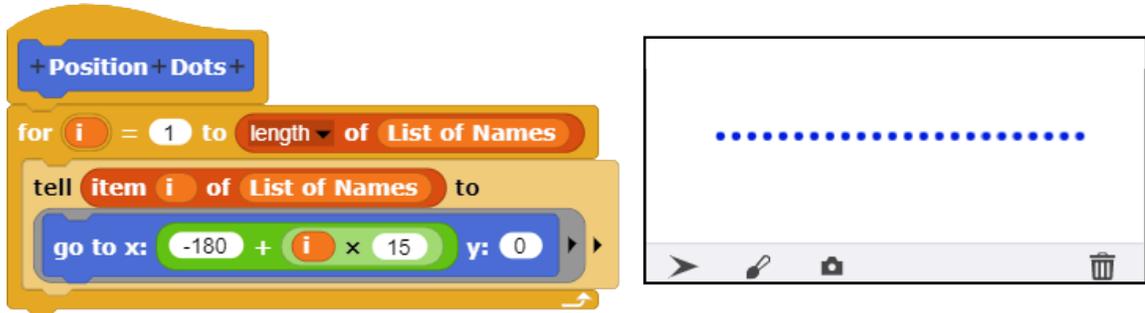
The clones created and named in this way then appear in the sprite corral.



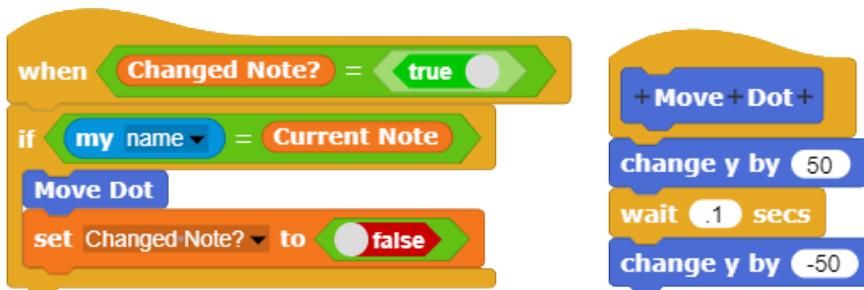
A script for creating a series of clones for each note can be implemented in a similar way and then encapsulated in the form of a block such as **Make Clones**. The list of names in this instance consists of note names. The name of a note is assigned to each clone representing two octaves of a piano keyboard: C4, C#4, D4, etc.



After the clones have been created, the **Position Dots** block positions the dots in a horizontal row across the stage.



Each clone contains a script that detects when a new note is played. This script was placed in the original sprite used as a template for the clones. When the clones were created, the script was also included in each clone.



When the **Play Note and Wait** block receives a request to play a note, it issues a call to the *Web Audio API* (a W3C standard for playing audio via the web) and retrieves the requested note. When the note is retrieved, the name of the retrieved note is stored in the variable, *Current Note*. At the same time, the value of a second variable - *Changed Note?* - is set to *True*.

When the variable *Changed Note?* is *True*, the script determines whether its name matches the currently played note. If there is a match, the dot is moved upward, and then back to its original position after a short delay. The *Changed Note?* variable is then reset to *False*.

The types of visualizations that can be created using this method are endless. A player piano scroll is one that is common in music visualizations. Light shows in which the intensity and color are triggered by the spectral composition of the music are also popular.

There are times when the clones may need to be deleted. They can be deleted individually or with a script. This script reverses the creation process, switching the status to *temporary* and then deleting the clone. (The **Delete This Clone** block works only for temporary clones.)



Topic 8.6 MIDI Keyboards

The *Musical Instrument Digital Interface* (MIDI) is a technical standard that describes ways in which electronic musical instruments can connect to one another. It was extended to include communications between a MIDI instrument, like a MIDI keyboard, and a computer.

The MIDI interface to TuneScope is an experimental feature that is likely to change in the future. The method for creating a visualization with input from a MIDI keyboard uses the TuneScope implementation at the time this was written (Spring 2022). The TuneScope MIDI commands can be imported from the *Library* menu (found under the *File* menu.)



The **Play MIDI Controller** block can be used to tell TuneScope that a MIDI keyboard is connected and available for use. A small number of MIDI keyboards used to test this feature are available in the dropdown menu. Other MIDI controllers can be specified by typing them into the input slot. (If the exact name of the MIDI controller connected to the computer is not typed correctly, the MIDI connection to TuneScope will not work.)

Once the musical instrument (*Piano* in the example) and the name of the MIDI controller (MPK mini 3 in this example) are specified, the Play MIDI Controller block is clicked once. The MIDI connection will then be active for the remainder of the session.



When a key is pressed on the MIDI keyboard, the key pressed is stored in the *Current Note* variable. The previously developed music visualization code developed for the **Play Motif** block also is activated by the notes played on the MIDI keyboard.



In addition to displaying the current note when a key on the MIDI keyboard is pressed, the corresponding MIDI number is displayed in a variable named *Current Note MIDI*. Each note has a corresponding MIDI number. C4 corresponds to the MIDI number 60. C#4 corresponds to the MIDI number 61, D4 corresponds to the MIDI number 62, and so on. MIDI numbers can be useful for transposing a series of notes to a different scale.

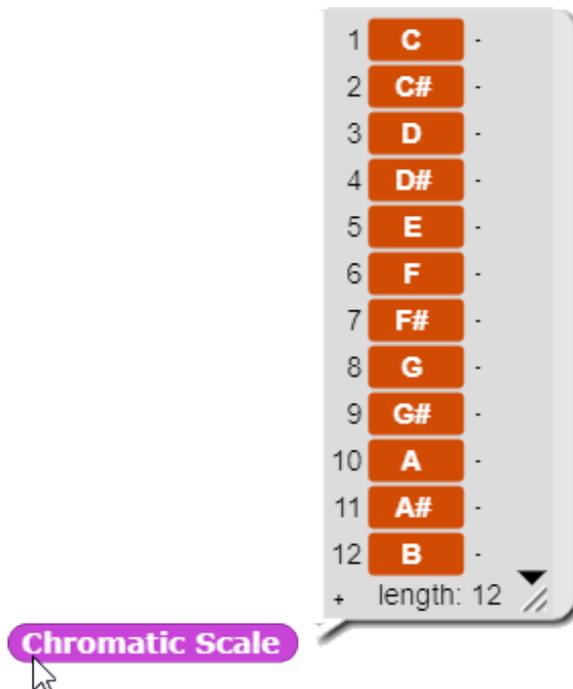
The ability to detect when a MIDI key is pressed and take an action in TuneScope based on the keypress opens the door to creation of many kinds of interactive music programs.

Appendix A

TuneScope Blocks Introduced

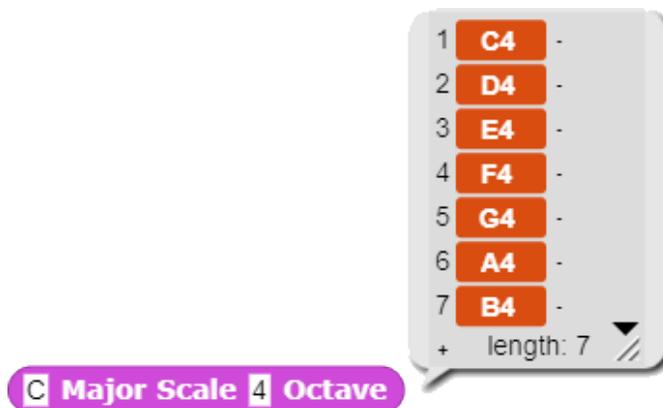
Chromatic Scale

The **Chromatic Scale** block reports the twelve notes of the chromatic scale.



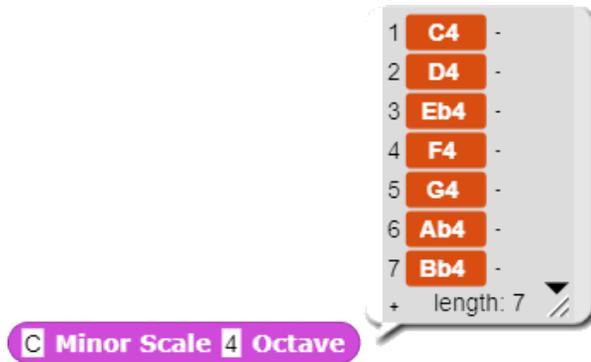
Major Scale

The **Major Scale** block reports the seven notes of a major scale in a specified octave.



Minor Scale

The **Minor Scale** block reports the seven notes of a minor scale in a specified octave.



The image shows a software block for a minor scale. It is a purple rounded rectangle with the text "C Minor Scale 4 Octave". A callout box points to the block, displaying a list of notes: 1 C4, 2 D4, 3 Eb4, 4 F4, 5 G4, 6 Ab4, 7 Bb4. Below the list is a plus sign, the text "length: 7", and a small icon of a pencil and eraser.

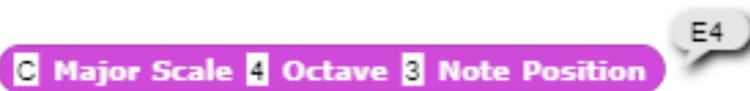
Interval between Note 1 and Note 2

The **Interval between Notes** block reports the number of steps between two notes within a major scale.

Interval between Notes E4 and F4 in the F Major Scale

Major Scale Note Position

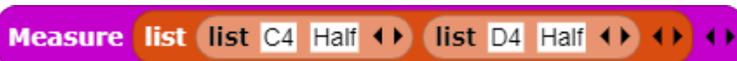
The **Major Scale Note Position** block provides the note associated with any position in any major scale. A parallel block provides this information for the minor scales.



The image shows a software block for a major scale note position. It is a purple rounded rectangle with the text "C Major Scale 4 Octave 3 Note Position". A callout box points to the block, displaying the note "E4".

Measure

The **Measure** block reports a group of notes that include durations.



The image shows a software block for a measure. It is a purple rounded rectangle with the text "Measure list list C4 Half <> list D4 Half <> <> <>".

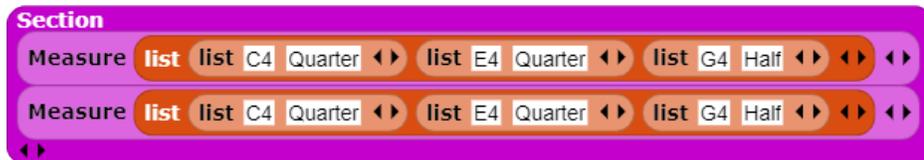
Beats in Measure

The **Beats in Measure** block calculates the duration of the notes in the measure and reports back the total number of beats (in quarter notes) as well as the number of beats (in quarter notes) required by the time signature.



Section

The **Section** block reports a list of measures.



Track

The **Track** block assigns an instrument to play a group of notes.



Play Track

The **Play Tracks** block can then be used to play the tracks created by the TRACK block.



Appendix B

Constructing Code Blocks to Report the Notes in the Major and Minor Scales and the Intervals between Notes within a Scale

Major Scales

The major scales consist of the following seven notes within the twelve-note Western chromatic scale: 1 3 5 6 8 10 12. A major scale cannot have two notes consisting of the same letter. For example, if sharps were used in the F major scale, the letter “A” would be used twice:

F G A A# C D E

Therefore, “B Flat” is used in place of “A Sharp” to avoid duplicating the letter “A”.

F G A Bb C D E

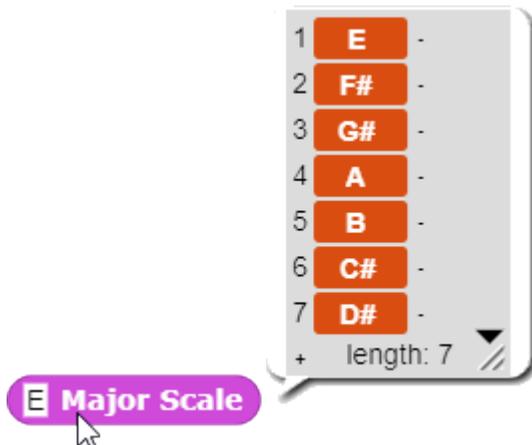
This table was used to construct a reporter block consisting of a **List of Major Scales**. The index number with each scale indicates at what point in the scale the notes shift from one octave to the next.

The image shows a Scratch code block titled "+ List of Major Scales +". It contains 14 "list" blocks, each representing a major scale. Each block starts with a "list" block containing the scale notes, followed by another "list" block containing the notes with an index number indicating the octave shift point. The scales and their index numbers are: C (7), C# (7), Db (6), D (6), Eb (5), E (5), F (4), F# (4), Gb (4), G (3), Ab (2), A (2), A# (2), Bb (1), and B (1). The code blocks are arranged in a vertical stack, with the word "report" visible on the left side of the stack.

The information in the **List of Major Scales** is then used to construct a **Major Scale** reporter block that reports the seven notes associated with any major scale.



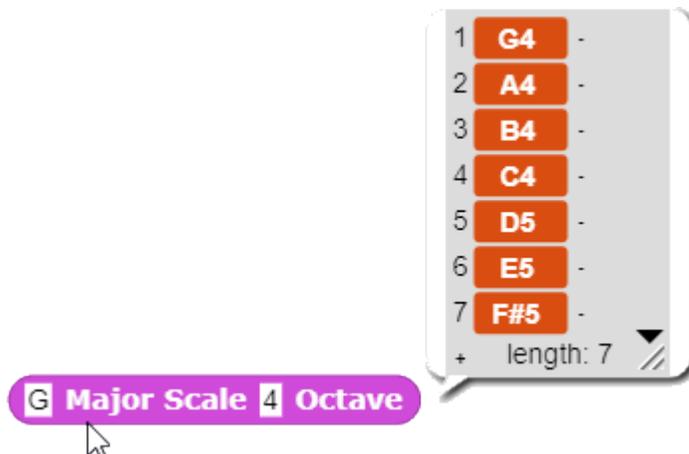
For example, this block reports that the following notes are associated with the *E Major* scale.



The Major Scale & Octave reporter block reports the specified octave as well as the note in each major scale.



For example, the following notes are associated with the *G Major* scale in the fourth octave. Each octave begins with the note "C". Therefore, beginning with the note "C", the octave shifts from the fourth octave to the fifth octave.



An index, **Major Scale Index**, was constructed to indicate the point at which the notes in each scale shift from one octave to the next. For example, in the case of the G Major Scale, the index indicates that first three notes are in the fourth octave, while the remaining notes are in the fifth octave.



The **Major Scale Index** reporter block retrieves the required information from the **List of Major Scales** reporter block.



Minor Scales

The procedure to report the position of the notes in the minor scale is almost identical to the similar procedure that reports the position of the notes in the major scale except that a “4”, “9”, and “11” replace “5”, “10”, and “12” in the list of positions in the chromatic scale.

Chromatic Scale	1	2	3	4	5	6	7	8	9	10	11	12
	C	C#	D	D#	E	F	F#	G	G#	A	A#	B
C Minor Scale	1	2	3	4	5	6	7					
	C	D	D#	F	G	G#	A#					

Intervals between Notes

The Interval reporter block reports the interval between any two notes in a major scale. For example, there is an interval of “1” between E4 and F4.



The *Interval* reporter block builds a table of the notes within that scale for the first seven octaves. It then locates the position of Note 1 and Note 2 within that list and subtracts the difference to obtain the interval between the notes.

```
+ Interval + between + Notes + Note 1 + and + Note 2 + in + the + Scale + Major + Scale +  
script variables Note 1 Position Note 2 Position list  
warp  
set list to list  
for i = 1 to 7  
set list to append list Scale Major Scale i Octave  
set Note 1 Position to index of Note 1 in list  
set Note 2 Position to index of Note 2 in list  
report Note 2 Position - Note 1 Position
```

Since the interval between notes determines whether two notes are harmonious or dissonant when played together, this information can be useful in constructing sequences of notes and chords.

Appendix C

New APCS Principles

Topic 7.2 Major Scales

CS Principle AAP-1.C Strings

In computer science, a *string* is an ordered sequence of characters. As opposed to a list, where each item in the list is a separate value, a string acts as a single value. For example, “(A, B, C)” is a list, but “ABC” is a string.

Application

In TuneScope, notes are represented using their scientific pitch notation. Each note consists of a letter name and an octave number. For notes that are sharp or flat, a modifier symbol is included between the note name and the octave number (e.g. C4 or C#4). These strings may be entered manually or assembled from drop down menus.

Topic 7.6 Music Intervals within Scales

CS Principle AAP-2.N List Indexing

Indexing is used to quickly access data from a list. Each item in a list has both a value and an index number. Index numbers reference the position of their corresponding values in a list. For example, in the table below, the value of the last item in the list is “Banana”, and its index number is “3”.

List Value	Apple	Orange	Banana
Index Number	1	2	3

Assigning an index number to each value makes it easier to not only identify the positions of items in a list, but also to manipulate and evaluate them.

Application

In TuneScope, all musical notes in a scale are indexed, as show below.

C Major Scale	C	D	E	F	G	A	B
Index Number	1	2	3	4	5	6	7

Indexing makes it possible to determine the position of each note in the scale relative to each other note. For example, to determine how many steps it is from E to A in the C Major scale, 3 is subtracted from 6, showing that A is 3 notes above E.

Adding octave numbers to the note names makes it possible to calculate positions across multiple octaves.