Musical Vibes with Palm Pipes

Understanding Frequency and Pitch of Sound Waves

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Based on Easter, G., Reitz, B., and Smith, W. (1996). Palm Pipes – "Handy" Musical Instruments. Unpublished paper presented by at Primary Operation Physical Science: Towson State University, Towson, MD. Accessed at http://crcst.org/Reitz/PTRA%20PALMPIPE%20Instructions.pdf

Focus on Inquiry

The student will measure the length of a set of ¾" diameter Palm Pipes and use an app (phone, iPad or tablet) to determine frequency and musical note for each pipe. Students then make similar measurements on a set of 1" Palm Pipes and then compare the relationship between the length of the pipe and its frequency between the two sets of pipes.

Lesson Content Overview

Students will investigate the relationship between frequency and pitch, as well as the length of a Palm Pipe and frequency and pitch.

Duration	Setting	Grouping	PTI Inquiry Subskills
90 minutes	classroom	groups of 4	2.6, 3.1, 3.2, 3.3, 3.7, 4.3

Lesson Components	Estimated Time	Inquiry Subskills Used	Technology Used	Level of Student Engagement	Brief Description
Engage	3-5 min	3.1	Internet video	1	Students will watch a PVC music video and observe how sound/music is made.
Explore	Act 1: 5 min Act 2: 15 min Act 3: 15 min	2.6, 3.1, 3.2, 3.3, 3.7, 4.3	• Guitar Tuner app • Calculator	3	Students will collect length, frequency and musical pitch data for a set of 15 (3/4") Palm Pipes.
Explain	(incorporated in Explore)				
Expand	~ 25 min	2.6, 3.1, 3.2, 3.3, 3.7, 4.3	• Guitar Tuner app • Calculator	3	Students will collect length, frequency and musical pitch data for a set of 15 (1") Palm Pipes and compare their results to those obtained in the Explore.
Evaluate ***wrap-up***	~10 min ~10 min		• Smart board to project music	3	*Wrap up:* Students will perform Palm Pipe music using the musical pitch data from the lesson.

Level of Student Engagement

1	Low	Listen to lecture, observe the teacher, individual reading, teacher demonstration, teacher-centered instruction
2	Moderate	Raise questions, lecture with discussion, record data, make predictions, technology interaction with assistance
3	High	Hands-on activity or inquiry; critique others, draw conclusions, make connections, problem-solve, student-centered

Next Generation Science Standards – Inquiry

NGSS Practice 4: Analyzing and Interpreting Data
NGSS Practice 6: Constructing explanations
NGSS Practice 7: Engaging in arguments from evidence
NGSS Practice 8: Obtaining, Evaluating and Communicating Information

Next Generation Science Standards – Physical Science

MS-PS4-1. A sound wave needs a medium through which it is transmitted.

Florida Science Standards - Inquiry

SC.7.N.1.2 Differentiate replication (by others) from repetition (multiple trials).

Florida Science Standards – Earth Science

SC.7.P.10.3 Recognize that light waves, sound waves, and other waves move at different speeds in different materials.

Materials and Advance Preparation

Materials List

Advance preparation:

- 8 10-ft lengths of ½" PVC (Sch 40) pipes [enough to make 10 sets of Palm Pipes]
- 4 10-ft lengths of 1" PVC (Sch 40) pipes [enough to make 5 sets of Palm Pipes]
- 12 gallon-size Ziploc bags
- Removable stickers (1"x2") or masking tape
- Metric tape measure
- PVC cutters

Group set for Explore:

- Palm Pipes (set of 15 pipes)
- Guitar tuning app on iPad, tablet or computer (e.g., *Guitar Tuner, by keuwlsoft)*
- 2 metric rulers (12" in length)
- Calculator for calculating average frequency

Student materials:

- Pen or pencils (Explore)
- Glass of water (Expand)
- Clorox wipes

Blackline Masters

1. **Blackline Master #1: Palm Pipe Exploration Sheet** (Explore, p 1; Expand, p 2)
2. **Blackline Master #2: Checking for Understanding: Palm Pipes**
3. **Blackline Master #3: Palm Pipe Songs**

Advance Preparation

1. Four 10-ft lengths of PVC pipe is enough to make five sets of two-octave Palm Pipes. I recommend making a total of 10 sets to keep group sizes small. It takes about an hour to measure and cut the PVC. About 30 minutes to put the tape on (step 2 below).

Palm Pipes Length & Frequencies **½" CPVC (Sch 40) pipe**			
No.	**Note**	**Length of pipe**	***Frequency***
#1	F	23.60 cm	349 Hertz
#2	G	21.00 cm	392 Hertz
#3	A	18.75 cm	440 Hertz
#4	B flat	17.50 cm	446 Hertz
#5	C	15.80 cm	523 Hertz
#6	D	14.00 cm	587 Hertz
#7	E	12.50 cm	659 Hertz
#8	F	11.80 cm	698 Hertz
#9	G	10.50 cm	748 Hertz
#10	A	9.40 cm	880 Hertz
#11	B flat	9.20 cm	892 Hertz
#12	C	7.90 cm	1049 Hertz
#13	D	7.00 cm	1174 Hertz
#14	E	6.25 cm	1318 Hertz
#15	F	5.90 cm	1397 Hertz

F Major Scale

	F	G	A	B flat	C	D	E	F
Musical Interval Ratio (Decimal)	9/8 1.125	10/9 1.111	16/15 1.106	9/8 1.125	10/9 1.111	9/8 1.125	16/15 1.106	

The size of the *musical interval* is determined by the ratio of the frequencies of the two tones that comprise the interval. This sequence of frequencies is the *natural scale*. Intervals having a frequency of **9/8** or **10/9** are called *whole tones* and those characterized by the **16/15** ratio are *half tones.*

2. Around the end of each pipe, wrap a piece of clear tape. This is where the students will write the name of the note down. This tape can later be removed and the pipes reused.
3. Make sure you can download and/or play the YouTube video (Engage):
   Do You Hear the Bottles Blow? https://www.youtube.com/watch?v=OAE8yOz4d1I (1:14-2:27)
   Bottle Whistling Entertainers https://www.youtube.com/watch?v=jloQ5wxqDP8 (1:31)

Lesson Information

Learning Objectives

1. The student will be able to use the data collected in this lesson (*condition*) to correctly (*standard*) state that sound is caused by a vibration traveling through a media (air, water, solid) (*task*).
2. The student will be able to correctly (*standard*) state, based on their data (*condition*), that if the pitch of a sound is high then the frequency is high (or fast) (*task*).
3. The student will be able to correctly (*standard*) state, based on their experiences in this lesson (*condition*), that the longer Palm Pipes have the lower pitch (*task*).

Prior Knowledge Needed by the Students

- General understanding that sound is produced by vibrations passing through a medium.

Background Information

When a disturbance passes through a medium, e.g. air, water, steel, or rock, the atomic particles vibrate. How often the medium's particles move back and forth during a measure of time is called the **frequency**. For example, if a particle of air moves back and forth "1000 longitudinal vibrations in 2 seconds, then the frequency of the wave would be 500 vibrations per second" (Henderson, 2015). A unit for frequency is called a **Hertz** (abbreviated Hz) and represents one vibration every second.

The musical term for how high or low a vibration sounds to our ears and brains (i.e., how our brains interpret the vibrations/second, or frequency) is called **pitch**. In the case of our Palm Pipes, the sound wave that is produced forms a *standing wave* within the pipe (Jones, no date). Since we've cut the pipes at specific lengths, the lengths produce frequencies that correspond to musical pitches. Again, pitch is how our brains interpret the vibrations we hear. Frequency is how many vibrations per second.

A sound that starts with a vibration in one location, can travel very far distances. This is because as each particle of the medium begins to vibrate, its neighbor particles also begin to vibrate at the same frequency. This is why we can hear someone shout at the 50 yard line of a football field and we can hear them at the goal line.

References

Henderson, T. (2015). *Sound waves and music - Lesson 2 - Sound properties and their perception: Pitch and frequency*. The Physics Classroom. Accessed at http://www.physicsclassroom.com/class/sound/Lesson-2/Pitch-and-Frequency

Jones, B. (no date). *Palm pipes: Vibrations in air columns*. Colorado State University, Little Shop of Physics. Accessed at http://littleshop.physics.colostate.edu/docs/PalmPipes.pdf

Lesson Procedure

Engage *(Time allotted: 3-5 minutes)*

1. Today our lesson is on the properties of sound. Let's watch this video:
   Blue Man Group: https://www.youtube.com/watch?v=Gr5R_Mz8oio (0:01 Adams Family Theme, 0:46 In The Jungle, end 1:50)
   Lidlurch: https://www.youtube.com/watch?v=bCGA7LKK5Sc (video game medley, beginning with Tetris, Mario Underworld Theme…)
   As the video plays, I want you to be able to discuss two things: What do you observe about the sound that's being made and how is the sound being produced. **(PTI 3.1)**
2. Okay. Now turn to someone in your group and share what you observed. Report out from groups.
3. Follow-up discussion questions:
   - **What did you observe? How is the sound produced? How do the performers change the sound that you hear?**

- **So how can we relate what we've seen in the video to how our voices make sound? In order for you to sing the song, what do you need?** [vocal cords, air]
- **What does each of these two things do?** [vocal cords vibrate the air, the air carries the sound wave]
- **How do you know if something is actually vibrating?** (Have students feel their throat.)

Explore

Activity 1: ***(~ 8 minutes)***

1. Give group of students one set Palm Pipes (ONE SET PER 4-5 STUDENTS). Have them closely observe the pipes and make as many observations as they can **(PTI 3.1)**. After one minute, share these observations as a class.
2. Within these groups, have students pair off, and have the pairs choose two Palm Pipes (one long or one short) from their sets. Have them observe and identify how their two pipes are similar and different **(PTI 3.1, 3.3)**. Once again, share and discuss these observations as a class. (~ 2-3 minutes)
3. Ask students if they were able to do anything with their pipes to make a sound. If a student has figured out how to produce a sound by hitting it on their palm, have them demonstrate it for the class. Have students listen and observe each other as they take turns vibrating their Palm Pipes. (~ 6 minutes)
   A. What does the pipe need in order to produce a sound?
   B. How are the vibrations of the two pipes similar and different?
   C. Which of your two pipes produces the lower sound? The higher sound? Can you make an observation that might help explain why this might be?
   D. What is a word we can use to talk about "high" and "low" sounds? [pitch or frequency - these words are related to the length of the sound waves that are traveling down the tube. Pitch is how the vibrations/second (frequency) are interpreted by our brain. Frequency is how many vibrations per second.**]**
   E. When we talk about high and low sounds, which sound do you think might be traveling faster than the other? [low sounds have lower frequencies…. Their rate of travel is slower than high pitches**.]**
   F. Does the pitch of the sound change depending on how hard you hit the pipes against your palm? [No, the pitch does not change. The sound is either louder or softer depending on how hard you hit**]. What words might we use to talk about the change in what we hear between a soft hit and a stronger hit to your palm? [**volume**]**
4. In the discussion, students might note that it is the air within the pipes that vibrates to produce a sound but that the two pipes vibrate at slightly different rates, or frequencies. We hear a change in pitch (low or high) between pipes… this is our brain interpreting the change in frequency (the vibration rate). Students will usually recognize that there is a relationship between the length of the pipe and the pitch of the sound produced.
   G. Why is it important and/or useful that different objects can vibrate at different pitches? Give them a minute to discuss this with their shoulder partner, and share out their ideas.

Activity 2: *(Time allotted: 15 minutes)*

1. Break the class up into eight groups. Give each group one set of Palm Pipes and 2 metric rulers.
2. Pass out the **Palm Pipe Exploration Guide** (**Blackline Master #1, p. 1**), one per student.
3. Model how to collect the data **(PTI 3.1, 3.2, 3.7)** on the first pipe (the longest one). Make sure groups have the Guitar Tuner app and access to calculator. Demonstrate (or better yet, have a student demonstrate) how to hit the pipe in order to get a good reading on the Guitar Tuner app. Ask, "Why do you think we must collect four frequency readings?" **(PTI 2.6)** Is this repeated collection of data replication or repetition (repeated trials)? **(SC.7.N.1.2)** [*There will be quite a bit of variation in the readings due to the relative sensitivity of the Guitar Tuner App sensors, ambient noise and perhaps even how we strike the PVC pipe. Multiple readings (or repeated trials) will give us a better idea of what the actual frequency is.*] Next, write down what note that PVC pipe is sounding on the Exploration Guide as well as the PVC tube (be sure to write is on the white label so it can be removed when we are finished with the activity.

4. Allow students about 15 minutes to measure their Palm Pipes, complete the table and to answer the three questions at the bottom. Consider using a countdown timer so students can pace themselves.
5. Discuss the answers to the questions on Blackline Master #1, page 1.
   H. As the length of the pipe increases, how does the pitch of the sound? (Choices: gets higher, gets lower, shows no change)
   I. What is the relationship between the length of the pipe and the frequency?
   J. Do you notice any other patterns in the data table above? (PTI 4.3)

Explain

1. See questions incorporated into the activities above.

Expand

Activity 4: Extending Learning with 1" Diameter Palm Pipes *(Blackline Master #1, p. 2) (Time allotted: 10 minutes)*

1. Repeat the steps of Activity 2 using 1" Diameter Palm Pipes. The focus here is to compare the results of frequencies for 1" diameter pipes to the results documented earlier with the ¾" pipes.
2. Have students collect all the data except for the last two columns first. This procedure is exactly like to Explore procedure. When they finish, model how to begin the calculations for the last two columns.
2. As you discuss the results of the Expand, take the opportunity to discuss and reinforce the following concepts as they arise:
   -- ***volume*** (loud, soft; the frequency doesn't change (i.e., the pitch remains the same) however the amplitude of the wave is bigger…. This is not something to focus on in this lesson since the Guitar Tuner doesn't show amplitude…)
   -- ***Palm Pipe length in relationship to pitch*** *(as the Palm Pipes length grows longer, the frequency is slower (or shows a lower rate) on the Guitar Tuner app.; shorter lengths of pipe have higher frequencies)*
   -- ***pitch in relationship to frequency*** *(pitch is how our brain interprets the sound waves arriving at our ear drum – they sound high or low; frequency is the rate at which the wave is traveling through the medium… so a particular frequency will sound like a specific pitch to our brains)*

Activities (optional)

1. Try blowing across the top of a pipe as if you were playing a flute. Does the pipe sound the same as when you tap it on your palm? Why or why not? **Safety note:** Wash the pipes with rubbing alcohol or a solution of 2 teaspoons household bleach per gallon of water before and after blowing across them.
2. Take one of the longer pipes and place it in a bottle of water so that the top of the pipe extends above the top of the bottle. Blow across it like a flute. What happens to the tone as you raise or lower the pipe in the bottle?
3. Try making another set of Palm Pipes out of 1/2-inch copper tubing. What happens when you strike these pipes against your palm? What happens when you blow across the top? How does the sound compare with the plastic pipes?
4. At a hardware store, purchase two rubber rings for each copper pipe. These rings should fit snugly around the pipes. Place one ring on each end of each pipe, then lay them on a table. Try tapping the side of each pipe with different objects—wooden and stainless steel serving spoons, for example. How does this sound compare with the other sounds you have made with the pipes?

Evaluate

FORMAL EVALUTION

Attached **Blackline Master #2 - Checking for Understanding: Palm Pipes**.

INFORMAL or OPTIONAL EVALUTIONS

1. Blackline Master #1 can be collected for a class grade.

WRAP UP: Making Music with Palm Pipes (Blackline Master #3) *(Time allotted: 10 minutes)*

1. Make sure that each student has one Palm Pipe (for a class of 35, this would mean using three of the sets). Pick up the remaining Palm Pipe sets and stow them in the plastic bags.
2. Using the attached music sheets for Palm Pipes (**Blackline Master #3)**, to have students play "Twinkle, Twinkle, Little Star" and "Row, Row, Row Your Boat" and/or other musical selections.

Supplementary Resources

Teachers

Life's a Lab Science Club (Dec 16, 2009). *Good Vibrations - the Science of Sound*. Accessed at https://www.youtube.com/watch?v=YN65wdSu37w

Excellent video about sound showing an elementary teacher teaching about sound using demonstrations: Singing Rods, Palm Pipes, Whirly Tubes, Tuning Forks, Space Phone, Slinky Compression Waves, & Thunder Tube.

CITATION OF SOURCES.

East Bay Educational Collaborative [www.ebecri.org]. (no date). Palm pipes. Accessed at http://odetie.pbworks.com/f/PalmPipesLesson.pdf

Henderson, H. (2003). Palm pipes. 2003 AP Physics Institute, Texas A&M University. Accessed at phys205.physics.tamu.edu/WebPageDocuments/PalmPipesChimes.doc

Easter, G., Reitz, B., and Smith, W. (1996). Palm Pipes – "Handy" Musical Instruments. Unpublished paper presented by at Primary Operation Physical Science: Towson State University, Towson, MD. Accessed at http://crcst.org/Reitz/PTRA%20PALMPIPE%20Instructions.pdf

__✓__ Yes, I cited all materials and resources used in this lesson.

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Lesson author signature

Blackline Master #1

Name _____ Date _____

Palm Pipe Exploration

1. You should have 15 Palm Pipes in your plastic bag.
2. Take the Palm Pipes out of the bag and arrange them in order from longest (on the left) to shortest (on the right).
3. Beginning with the longest pipe, measure your Palm Pipes in cm (to the nearest mm). Record your measurement on the data table, beginning with the longest at the top.
4. Next, download the app ***Guitar Tuner*** ***(by keuwlsoft)*** on your phone or tablet.
5. As your fill in your Average Frequency data, notice and record the name of the musical note is assigned to that frequency.
6. Record the musical note on the sticker or piece of tape you will find on one end of the pipe.

Palm Pipe Data							
Pipe Number	Length of ½" PVC pipe (cm)	Frequency					Corresponding Musical Note
		Test 1	Test 2	Test 3	Test 4	Average Frequency	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Making Sense of Pitch and Frequency

Looking at your data and thinking of your experiences with the Palm Pipes, answer the following questions.

1. As the length of the pipe increases, the frequency of the sound _____.
2. The sound coming from the Palm Pipes, how high or low it sounds to our ears is called _____. What is the relationship between this tone the Palm Pipe makes and the frequency?

   _____
   _____
   _____

3. What is the relationship between the length of the pipe and the frequency?

   _____
   _____

4. Do you notice any other patterns in the data table above?

Based on xxx (xxx)

Blackline Master #1, p. 2

Extending Your Learning with 1" Diameter Palm Pipes

1. Beginning with the longest pipe, measure your Palm Pipes in cm (to the nearest mm). Record your measurement on the data table, beginning with the longest at the top.
2. Next, download the app ***Guitar Tuner (by keuwlsoft)*** on your phone or tablet.
3. Calculate your average frequency.
4. Using your Average Frequency, assign the musical note that sounds when you play the Palm Pipe in the table.
5. Record the musical note on the piece of tape you will find on one end of the 1" PVC pipe.
6. Calculate the last two columns.

Palm Pipe Data – 1" Palm Pipes

Pipe #	Length of 1" PVC pipe (cm)	Frequency (ν)					Corresponding Musical Note (from your tuner app)	Musical Relationship between adjacent notes	
		Test 1	Test 2	Test 3	Test 4	Average Frequency		Set up Frequencies Division Equation	Divide and round to the 0.001 place)
1								$\nu_{Pipe1} \div \nu_{Pipe2}$	=
2								$\nu_{Pipe2} \div \nu_{Pipe3}$	=
3								$\nu_{Pipe1} \div \nu_{Pipe4}$	=
4								$\nu_{Pipe1} \div \nu_{Pipe5}$	=
5								$\nu_{Pipe1} \div \nu_{Pipe6}$	=
6								$\nu_{Pipe1} \div \nu_{Pipe7}$	=
7								$\nu_{Pipe1} \div \nu_{Pipe8}$	=
8								$\nu_{Pipe1} \div \nu_{Pipe9}$	=
9								$\nu_{Pipe1} \div \nu_{Pipe10}$	=
10								$\nu_{Pipe1} \div \nu_{Pipe11}$	=
11								$\nu_{Pipe1} \div \nu_{Pipe12}$	=
12								$\nu_{Pipe1} \div \nu_{Pipe13}$	=
13								$\nu_{Pipe1} \div \nu_{Pipe14}$	=
14								$\nu_{Pipe1} \div \nu_{Pipe15}$	=
15									

Comparing the Pitch and Frequency of ½" and 1" PVC Palm Pipes

Looking at your data and thinking of your experiences with the Palm Pipes, answer the following questions.

1. What relationship is there between the pitch and frequency of the ½" and 1" Palm Pipes?

   _____

   _____

2. Does the pitch change if you hit the Palm Pipe harder? ____ Yes ____ No Explain your answer.

   _____

   _____

3. In the last two columns you calculated a value between 2 adjacent Palm Pipes. Do you see any patterns? If so, what patterns do you see?

   _____

   _____

This Expand was created by Dr. Pam Blanchard.

Name _____ **Date** _____

Checking for Understanding: Palm Pipes

1. The longer the Palm Pipe, the _____ (higher, lower) the pitch. (LO #3)

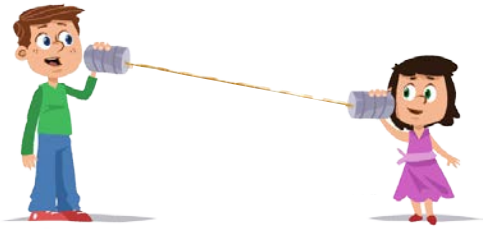
2. What is the relationship between the frequency of a Palm Pipe and the pitch of the sound? (LO #2) _____
_____
_____

3. In reading class, Frances was studying about Greek Mythology. She read about Pan, the god of fields, groves, and wooded glens. Pan is often drawn with a set of hollow reeds tied together with string. This instrument is known as 'Pan's pipes.' In the picture to the right, where should Pan blow if he wanted to hit a low note? (LO #3)
   A. Pipe X
   B. Pipe Y
   C. Pipe Z

4. Where on Pan's pipes would he have to blow to get a sound with the highest frequency? (LO #3)
   A. Pipe X
   B. Pipe Y
   C. Pipe Z

5. Palm Pipes make sound because (LO #1)
   A. hitting the end of the tube causes the air to vibrate inside the tube.
   B. hitting the end of the tube causes a pitch to vibrate inside the tube.
   C. hitting the end of the tube causes frequencies to vibrate inside the tube.

6. Ibrahim and Sally made a tin can phone using two tin cans with a string. How is their tin can phone similar to a Palm Pipe? (PTI 3.3, LO #1) _____
_____
_____
_____



7. The collecting of four frequency readings for each Palm Pipe is an example of… (SC.7.N.1.2)
   A. repetition.
   B. replication.

Image from http://stkevinsblog.ie/?p=238

Blackline Master #3, p. 1

TWINKLE, TWINKLE LITTLE STAR

(Nearly the same tune as the "Alphabet Song")

Twin - kle, twin - kle lit - tle star, How I won - der what you are

Melody: F F C C D D C B♭ B♭ A A G G F

Harmony: C C A A B♭ B♭ A G G F F E E C

Up a - bove the world so high, Like a dia - mond in the sky,

Melody: C C B♭ B♭ A A G C C B♭ B♭ A A G

Harmony: A A G G F F C A A G G F F C

Twin - kle, twin - kle lit - tle star, How I won - der what you are

Melody: F F C C D D C B♭ B♭ A A G G F

Harmony: C C A A B♭ B A G G F F E E C

HAPPY BIRTHDAY

Hap - py birth - day to you, hap - py birth - day to you;

C C D C F E C C D C G F

Hap - py birth - day dear Ein - stein;

C C C A F E D

Hap - py birth - day to you!

B♭ B♭ A F G F

LONDON BRIDGE

Lon - don bridge is fall - ing down, fall - ing down, fall - ing down;

G A G F E F G D E F E F G

Lon - don bridge is fall - ing down, my fair la - dy.

G A G F E F B D G E C

Blackline Master #3, p. 2

ROW, ROW, ROW YOUR BOAT

Row, row, row your boat gen - tly down the stream;
C C C D E E D E F G

Mer - ri - ly, mer - ri - ly, mer - ri - ly, mer - ri - ly,
C C C G G G E E E C C C

Life is but a dream.
G F E D C

WHERE IS POINTER?

(or Are You Sleeping?)

"Where is Point - er? Where is Point - er?" "Here I am! Here I am!"
C D E C C D E C E F G E F G

"How are you to - day sir?" "Ver - y well I thank you."
G A G F E C G A G F E C

Run a - way, run a - way.
C G C C G C

Additional music at http://odetie.pbworks.com/f/PalmPipesLesson.pdf