

# APOTOME & LEIMMA

## USER GUIDE

By Khyam Allami

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As Apotome and Leimma share many fundamental principles, this guide is designed for both and contains a lot of contextual information.

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Apotome tutorial video → <https://vimeo.com/503451447>

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# Introduction

**Apotome** is a transcultural browser-based generative music environment focused on octave-repeating tuning systems and their subsets (scales/modes). It is designed to be used alongside its sister application, **Leimma**, also a browser-based tool, which allows for the creation of new tuning systems and subsets, or exploring existing ones.

Both Leimma and Apotome are non-commercial and were created as **tools** for **music-making** and/or **music-learning**. Although they can create sound through their integrated web synthesisers, their purpose is *not* synthesis or sound design. They are attempts to create transcultural, digital music making tools that can facilitate the exploration of melodic possibilities from musical cultures long repressed by Western music theory, modern music technology and the hegemony of 12-tone equal temperament.

It is obviously non-Anglo-European cultures that have been mostly affected and disfigured by 12-tone equal temperament, but it is not exclusive to them. Anglo-European cultures have been affected too, as have the efforts of 20th century experimental Anglo-European composers. Tuning affects all music, and although the difference in comparison to 12-tone equal temperament is sometimes subtle, it is precisely these subtleties that make a difference. In this sense, “transcultural” could be a good word to describe the nature of these tools.

By implementing the relationship between tuning systems and their subsets in a simple and intuitive way, and utilising both web synths and MIDI, Leimma and Apotome can be integrated into any music-making or music-learning environment. They allow the user to learn then make, or make then learn, or just make! Whatever suits the user’s individual process.

Leimma and Apotome are also designed with educators and digital teaching in mind - in-person or online. Being browser based they are easy to access, and having clear, intuitive interfaces helps make them inviting for those new to the subject. All the while they’re also capable of satisfying the advanced user.

Tuning is a complex subject and has occupied countless hours of some of the entire world’s greatest minds for millennia - but the tools to aid us in teaching, learning and exploring it, need not be. Think of the bamboo pipes of ancient China, or even the monochord used by Euclid - simple tools, behind which lie incredible philosophical, technical, scientific, practical and musical ideas.

Enjoy your explorations and please share your thoughts, experiences, and work with me by email, [ka@khyamallami.com](mailto:ka@khyamallami.com), I would love to read and hear them.

Khyam Allami  
Berlin, January 2020

## Credits

Apotome and Leimma were created in 2020 by musician/composer [Khyam Allami](#) and creative studio [Counterpoint](#). They form a part of Allami's PhD in composition at the Royal Birmingham Conservatoire (part of Birmingham City University), and were launched publicly as part of Berlin's [CTM Festival 2021](#).

**Khyam Allami:** Concept design and direction, research, composition

**Tero Parviainen:** Software development, UI engineering, concept design, generative music system design

**Samuel Diggins:** Design and creative direction, concept design, UI engineering

OBXD, DEXED, and Yoshimi Web Audio Modules by Jari Kleimola <https://wam.fm>

The development of Apotome was funded via the [AHRC Midlands4Cities Doctoral Training Partnership](#) with additional support from [CTM Festival](#).

## Contact Information

If you have any questions or queries, please contact Khyam Allami via email on: [ka@khyamallami.com](mailto:ka@khyamallami.com)

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# System Requirements

Apotome and Leimma will only run with full MIDI functionality in **Chrome** or **Chromium based** browsers e.g. **Brave**, on a desktop or a laptop.

If you are happy to work without MIDI, you can use Safari or Firefox.

Click [here](#) to download Chrome.

Click [here](#) to download Brave (Chromium).

Click [here](#) for a list of browsers that support MIDI.

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# ON TUNING SYSTEMS AND SUBSETS

## What is a Tuning System?

A tuning system is a systematised series of pitches used to make music. These series are referred to as divisions of a larger interval, usually an octave. Most often, they are unequal divisions i.e. each division doesn't have the same size.

Almost all tuning systems across cultures and histories are both cyclic and octave-repeating. This means the selected divisions are all within the range of one octave and the same in every octave.

There are of course non-octave-repeating exceptions, i.e. systems that divide intervals other than an octave, like some Indonesian Gamelan tunings, or experimental 20th century systems like [Bohlen-Pierce](#).

To allow the most sonic freedom, Leimma and Apotome only work with octave repeating systems for now. Read more about why [below](#).

## What is a Subset?

A subset is a selection of the different divisions used in a tuning system at any one time, most often between 3 to 12. In music these are rendered as scales or modes. We chose to name them subsets, because defining them as scales or modes depends on how they are used.

For example, the Middle Eastern maqām system uses 17, 19, 24, 25 or 53 divisions of an octave, but the maqāmāt (modes) themselves are mostly heptatonic subsets (7-note), with extra divisions used for melodic colour or ornamentation per maqām. The extra divisions are rarely more than 2 or 3. Maqām modulations are then used to navigate between the different subsets. The same subset can be rendered in different ways, giving it its modal characteristics, for example, starting in the upper octave and descending down to the root.

The North Indian rāga tradition is similar in that it relies on a tuning system that is divided into 22 divisions called śrutīs, and each rāg uses a subset of those divisions in either pentatonic (five notes) or heptatonic (seven notes) formations, with additional divisions used in ascending or descending phrases to bring out the rāsa (flavour) of the rāg.

## What are Ratios?

In mathematics, ratios are expressions of the relationship in quantity, amount, or size between two or more things.

In music, they historically represent the relationship between an open string and a divided string, or two different string or pipe lengths.

Ratios are used for this purpose in music because they are the most accurate way of representing the relative relationship between two things, without relying on fixed measurements.

When using musical ratios, everything is relative to a fundamental ratio of 1:1. This would be the equivalent of the frequency of an open string which we want to divide, regardless of what that frequency is (i.e. what pitch it sounds).

In the case of two panpipes or two strings of a harp, imagine that they have the lengths 20 cm and 10 cm. If we take the 20cm pipe as our reference (therefore 1:1), the frequency of the pitch generated by the 10cm pipe would be double the frequency generated by the 20cm pipe. This is because it is half the length and therefore the cavity causes the air blown to produce a frequency that is higher, or more accurately, double the frequency of the longer pipe. These pitches can be expressed as having the ratios of 1:1 (20cm pipe) and 2:1 (10cm pipe).

If we decided we wanted to maintain the same relationship but starting with a pipe of a 30cm length, we would just need to use the ratio to figure out the length of the second pipe.

If we want the second pipe to have the ratio of 2:1, then we treat the first pipe of 30cm as equal to 2 parts, and the second pipe as equal to 1 part. Calculated, this would be 30cm divided into 2 parts = 15cm per part = one part is 15cm.

A division of stretched string on a musical instrument exactly in the middle, would also be expressed as having a value of 2:1 for the same reason. The full open string would be our 1:1. If we want to divide it at the ratio of 2:1, we would treat the full string length as having 2 parts, divide the full string length into 2 and place our division at the distance of 1 part, which would be exactly half way along the string.

## What are Cents?

Cents are a unit of measurement of pitch, much like centimeters for distance. They were developed by English mathematician Alexander Ellis and first published in his 1875 (first edition) English translation of and commentary on German physicist Hermann von Helmholtz's "On the Sensations of Tone" originally published in 1863 (first edition).

Ellis devised the cents measurement system in order to be able to compare different intervals to equal temperament, and used cents values in his English translation instead of the ratios found in Helmholtz's original ([Helmholtz 1863](#)).

“When the interval numbers, that is the pitch numbers of two notes, have been found (or the interval ratio [...]) it is necessary, in order to have a proper conception of the interval itself by comparison with a piano or other instrument tuned in intentionally equal temperament, to determine the number of cents or hundredths of an equal Semitone, in that interval” ([Ellis 1885:446](#)).

The cents system divides the octave into 1200 cents and therefore 100 cents per semitone in equal temperament. It is an excellent alternative to ratios for comparative purposes because it gives a clearer indication of the distance in pitch from one note to another.

Ratio	Cents (3 decimal places)	Cents (rounded)
1:1	0.000	0
9:8	203.910	204
4:3	498.045	498
3:2	701.995	702

Though when it comes to tuning, using simple number ratios where possible is more accurate, even if that level of accuracy is often purposely modulated (see [Are Tuning Systems Fixed?](#) below).

For information on the calculation of cents see [Ellis 1885:447](#).

## How are Tuning Systems created?

Historically, tuning systems were developed by relative measurement using fractions and ratios. These were then rendered on instruments such as Harps/Lyres (Mesopotamia), Bamboo Pan Pipes (Ancient China), Monochords (Ancient Greece) and Ouds (Middle East).

A great and very simple example is the Chinese system attributed to Huang-Ti, the Yellow Emperor from around 2967 BC ([Nakaseko 1957:149](#)). Archeological findings date the earliest tuned musical bamboo pipes to the Shang I Dynasty 1766 BC - c. 1400 BC ([Kuttner 1964:121](#)), but this system was first recorded by Kuan-tzŭ around 300 BC ([Nakaseko 1957:147](#)).

This method used bamboo pipes to create a 12 tone system (although Kuan-tzŭ only gave calculations for a 5 tone pentatonic system).

“The length of the fundamental pipe, huang-ching (yellow bell), is 9 ts'un, that is 8.1 ts'un by more recent measurement systems. The measuring system of the Chou dynasty was nonary. A ts'un had nine parts, hence nine ts'un, on a

decimal system would be 8.1 ts'un. Eighty-one, then, is the number of huang-chung. Earlier documents use this number in calculation, later documents, nine. [...]

The lengths of the subsequent pipes are obtained by dividing each new one into three parts, and subtracting one part and adding one part alternately; that is, taking alternately a pipe shortened by  $1/3$ , producing a pitch a fifth higher, and a pipe lengthened by  $1/3$ , producing a pitch a fourth lower.

In proportional fractions the former would be represented by  $2/3$ , the latter by  $4/3$ . The generation by  $2/3$ , or progression up a fifth, is expressed as inferior (Yin), since the resulting pipe is shorter, that by  $4/3$  or progression down a fourth, as superior (Yang) since the resulting pipe is longer.

In this arrangement, the six sounds obtained by superior generation are called Yang sounds, the other six, obtained by inferior generation, Yin." [Nakaseko \(1957:149\)](#)

Earlier systems, such as that used in Mesopotamia during the Old Babylonian period around 2000-1600 BC ([Mirelman 2013](#)), are presumed to have been created by ear. Researchers have proposed that they may have developed a mathematical basis in the late Babylonian period around 600 BC ([Crickmore 2008:19](#)) by using a sexagesimal mathematical system (base 60) which originated with the Sumerians around 3600 BC ([Laki 1969](#)).

It is important to note that the Mesopotamian system was heptatonic and indicates in cuneiform script how to tune a nine-stringed harp by cycling through seven different modes ([Mirelman 2013](#)). This system is consistently referred to in literature as Pythagorean tuning, even though it predates the Pythagoreans by 1000-1500 years, and even though the ancient Greek "Pythagorean" modes are identical to the Mesopotamian modes in tuning and interval structure.

The Nāṭyaśāstra from India, attributed to Bharata Muni and dated between 200 BC-200 CE, does not give precise measurements but does mention that the octave is divided into 22 śrutis. It gives the distances in śrutis for two main heptatonic subsets and goes on to explain how to achieve the full 22 śrutis by detailing an experiment that involves using two vīnas with the same heptatonic divisions, and then slowly detuning one by a specific amount of śrutis whilst comparing to the first which remains untouched ([Jairazbhoy 1975:40](#)).

Although the Greek Pythagoras (500 BC) is often credited with discovering the relationship between mathematics and music using divisions of a string, we can see that these relationships were already documented centuries earlier.

The historical analysis by Barker ([1981:1-15](#)) shows that the early Greek methods were based on string lengths, similar to the Mesopotamians, and that the earliest writings

about the division of a string using a monochord are in the *Sectio Canonis* from around 300 BC which is debatably attributed to Euclid ([Barker 1981:190-208](#)).

Greek theorists of the Pythagorean school onwards used the ratios 1:1, 2:1, 3:2 and 4:3 to create an octave repeating system that spanned the range of two octaves. It was made up of various tetrachords (series of 4 pitches) and called The Greater Perfect System. Although today we are often told that the Greek system was diatonic, the analysis of historical writings shows that it was far more varied, including divisions of a third-tone and a quarter-tone ([Barker 1981:140](#)).

In the Middle East, Arab theorists from the 9th century onwards such as Al-Kindi, Al-Farabi, Ibn Sina, Al-Urmawi and others built, upon the Greek theories and mathematics of ratios by developing systems that represented their local tonalities by adding frets or markings to the Oud ([Beyhom 2020](#)). These included systems of 17, 19 and 25 divisions of an octave.

The Turkish-Ottoman system was initially based on 53-commas (so called Holdrian commas), whereby the interval of 9:8 (a tone of approx. 204 cents) was divided into 9 commas. Since the 1970s it has slowly been replaced by 53 equal divisions of the octave.

The Persian system most likely developed independently based on the same fundamentals. The earliest written documentation is by the Arab mathematician Al-Farabi (d. c. 950 AD) who gives a precise ratio value for a division on the oud that he terms *wusṭa al-furs*, the middle finger of the Persians. For a comprehensive overview of Middle Eastern tuning systems see [Forster 2010:610-744](#).

In the 20th century, many theorists and composers have created tunings using various equal divisions of the octave such as Wendy Carlos did with her [Alpha, Beta and Gamma](#) systems. They have also utilised what is known as Just Intonation, a method of creating tuning systems with simple number ratios taken from intervals present in the Harmonic and Subharmonic Series. For more about Just Intonation see [Nicholson and Sabat 2018](#).

## Exercise

Try to calculate the lengths by adding and removing a third as per the ancient Chinese example above when our reference length is 81mm (1:1 = 81):

$$81 / 3 = 27 \mid 81 + 27 = 108$$

$$108/3 = ??$$

1:1	Add one third to previous	Remove one third from previous	Add one third to previous	Remove one third from previous
81mm	108mm			

[Answers at the end of the document :-\)](#)

## Are Tuning Systems Fixed?

An important point to keep in mind is that although tuning systems look perfectly devised and defined when displayed in writing, they are rarely rendered with such rigid and exact values in practice. The perfect rendition only really occurs when using digital tools, and therefore it should be treated as an accurate guide to start from, and not a fixed end.

In many musical traditions, certain divisions are slightly altered during performance to give the melodies being rendered more character. So tuning systems should be thought of as theoretical models that are very subtly malleable, depending on the aesthetics of the musical culture they come from.

Performers of non-fixed-pitch acoustic instruments will always vary pitches slightly, playing them a little higher or a little lower, sometimes depending on phrasing, sometimes not.

Even acoustic pianos are rarely tuned in exact, perfect, precise equal temperament. More often than not, they use a [stretched tuning](#) to accommodate the inharmonicity of the strings. Musicians using fixed pitch instruments such as pitched percussion obviously rely on the tuning of the instrument, but even their tuning is affected by temperature and humidity.

The Just Noticeable Difference (JND) for frequency, refers to the smallest change in frequency that may be perceived by the listener. According to Sethares, testing has shown “that the JND can be as small as two or three cents, although actual abilities vary with frequency, duration and intensity of the tones, training of the listener, and the way in which JND is measured” ([Sethares 2005:44](#)).

A good practice when using synthesisers is to use a very slow LFO to gently modulate the oscillator frequency just below the JND threshold. Even +/- 1 or 2 cents will make a subtle but noticeable difference to the quality of the sound, especially when using multiple voices or multiple instruments. This is why chorus effects always help thicken and enrich recorded sounds.

## What is equal temperament?

Twelve tone equal temperament, also referred to as 12-EDO or 12-TET, is a tuning system that divides the octave into twelve equal divisions first published accurately in the 16th century, and more widely adopted in Europe in the 19th century.

Since the introduction of digital and digitally controlled synthesisers in the late 1980s, it has become the most hegemonic tuning system, imposed on the world due to the

proliferation of precisely controlled analogue and digital electronic instruments and digital music software, that rarely allow the use of any other tuning.

The origins and attribution of Equal Temperament are disputed as they seem to have occurred in both Europe and China around the same time.

In his consistently cited book *Tuning and Temperament: A historical survey*, J. Murray Barbour states that “the first precise mathematical definition of equal temperament was given by Salinas” in 1577 ([Barbour 1957:25](#)). He then follows by stating that “The first known appearance in print of the correct figures for equal temperament was in China, where Prince Tsaiyü’s brilliant solution remains an enigma, since the music of China had no need for any sort of temperament” but without mentioning any dates.

According to Kuttner, Chu Tsai-yü’s three main works—*Lü Hsüeh Hsin Shuo*, published 1584, *Lü Lü Ching I*, written 1595/96, but probably not published before 1606 and *Suan Hsueh Hsin Shuo*, published 1603 —all “contain substantial contributions to the numerical definition of equal temperament, partly in monochord tabulations of amazing precision, partly in highly detailed mathematical calculations” ([Kuttner 1975:166-167](#))

Barbour then adds that “more significant for European music, but buried in manuscript for nearly three centuries, was Stevin’s solution” ([Barbour 1957: 25](#)), which was written by Stevin in his *Van de Spiegeling der Singconst* c. 1600 but not published until 1884 ([Stevin 1884](#)).

On this, Kuttner states that “at roughly the same time as Chu completed his above three works, Simon Stevin (1548-1620), a distinguished Flemish mathematician and inventor, drafted—with no particular care or urgency—an essay containing the mathematical formulation of equal temperament as  $12\sqrt[12]{2}$  for the first time in Western musical theory; he continued with the calculation of a monochord which defines the 12 semitone values, correct to four decimal places, as 12 successive powers of the twelfth root of 2. He then sent the manuscript to a scholarly friend where it eventually got misplaced or forgotten. Obviously Stevin was not much interested in a publication of his findings because he did not attach too much significance to them. The essay remained forgotten, apparently, because the recipient as well did not consider it as something of real scientific consequence. Thus, it took until 1884, when it was rediscovered and edited by de Haan, to be published for the first time” ([Kuttner 1975:167-168](#)).

Later in his book, Barbour mentions that “the earliest numerical approximation for equal temperament comes from China. About 400 A.D., Hô Tchhêng-thyên gave three monochords for the chromatic octave, with identical ratios, but with the fundamental taken as 9.00, 81.00, and 100.0 respectively” (Barbour 1957:84). This relies on a reference to Maurice Courant’s historical essay *Sur La Musique Classique Des Chinois*, published in the *Encyclopédie de la musique et dictionnaire du Conservatoire* in 1913, edited by A. Lavignac, but Courant’s original doesn’t clearly state it’s source.

To conclude his research, Kuttner states that “it seems pointless to attempt a qualitative evaluation of the two solutions with a view to label one or the other as superior. Both authors proceeded within the framework of their own cultural traditions and created perfect solutions consistent with their different scientific surroundings. Neither Chu nor Stevin can be recognized as "inventors" of equal temperament, for the following reasons. In China the problem of such tempered tuning had been known for as many centuries as in Europe. Stevin's definition and calculation was not needed in Europe where practical tunings with satisfactory approximations to good tempering had been known and used for almost hundred years before his work. In Chinese musical practice equal temperament was neither needed nor desired before or after Chu's publications, thus unfortunately making his achievement irrelevant for his nation” ([Kuttner 1975:200](#)).

For more detailed information see [Duffin, R. W. \(2008\). How equal temperament ruined harmony: \(and why you should care\). New York, W.W. Norton.](#)

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# ABOUT LEIMMA AND APOTOME

## What do the names mean?

Leimma and Apotome take their names from musical intervals devised by ancient Greek theorists, and are often referred to as Pythagorean intervals.

A leimma (also written; limma) has a value of  $256/243$  or 90.225 cents and an apotome has a value of  $2187/2048$  or 113.685 cents. Arab theorists referred to the limma as *al-bāqīya* and the apotome as *al-infiṣāl*, and alongside the interval of a Pythagorean comma ( $531441:524288$  or 23.460 cents), used them to delineate tuning systems on the oud ([Farmer 1957:459](#)).

Although the historical writings relating to tuning systems go back to approx 2500 BC in Mesopotamia ([Mirelman 2013](#)) and precisely tuned lithophones existed in China around 900 B.C ([Kuttner 1964:122](#)), it is often Greek, i.e. Western, theorists who are given the credit for developing the core tuning systems and theories used today.

The use of these terms as names is a desire to reappropriate them in today's context, whilst advocating for a celebration of difference across cultures, ideas, methods, and sounds in music making.

## What about Bias?

Apotome and Leimma are attempts to create transcultural digital music making tools that are free of as much bias as is possible, but we are aware that we can't avoid it all.

Myself, Tero and Sam from Counterpoint have had to maintain vigilance and self-critique in order to regularly check our thought processes and ideas. It has been difficult, because we too suffer from inherited biases that are part of our subconscious. Everything from the terminology, to the functionality has gone through many iterations in order to reach where we are today, but it still isn't enough.

With regard to tuning, I am confident that Leimma and Apotome can render any tuning system from any culture as accurately as possible. When it comes to timing, and particularly groove, this is still lacking. Mostly this is due to our focus on the subject of tuning. Hopefully we can introduce an equally inventive feature for grooves in the near future.

As for the tuning systems currently in the database, they are clearly lacking! This is because we are trying to make sure that we only include tuning systems that have proper references to sources. Doing this takes a lot of time that I didn't have before the launch, but we will constantly be adding them. You can always input tuning systems yourself and save them in [My Tunings], but if you would like to submit

something for us to include in the database, please email it to me with as many details as possible, especially sources with links or proper citations: [ka@khyamallami.com](mailto:ka@khyamallami.com).

## Why only Octave Repeating tuning systems?

Leimma and Apotome only work with octave repeating systems due to the restrictions by software and hardware manufacturers that don't allow the use of Midi Tuning Standard (MTS).

To get around this, Leimma and Apotome use Midi Pitch Bend messages in order to allow the users total freedom in using any sound source they like, from the internal web synths, to any external software or hardware synthesisers or sample libraries via MIDI.

Read more about this problem with MTS implementation in my article [Microtonality and the Struggle for Fretlessness in the Digital Age](#), published in the CTM Festival magazine 2019.

## Why in-browser and not a plugin or standalone software?

Using the browser is not only a novel way to engage with music making software, it also helps keep things accessible for those who don't have powerful computers to run the latest software, or the money to purchase it.

## How does Leimma work?

Leimma allows you to explore, hear and play existing tuning systems or create your own with little to no specialist knowledge and nothing but access to a laptop and a web browser.

You can also connect a MIDI keyboard to play the tunings, and route the MIDI to internal software or external hardware synthesisers to hear the tunings with any sound you like.

## How does Apotome work?

Apotome generates material based on the parameter settings that you choose. It is not passive, you must engage with it to create something.

As with most generative systems, most of Apotome's parameters work by probability, using sliders, buttons and switches.

There are very minimal algorithms at work in the code of Apotome. Essentially, you are creating your own algorithms, or variations on your own algorithms, when you manipulate any parameters.

Apotome may not generate the exact music you would release as a complete work unto itself, but we hope it will provide you with a resource to go to for inspiration, to capture ideas from, and develop into something you would be proud of.

## **How do they accurately render the tunings?**

Both Leimma and Apotome render tunings by using Midi Pitch Bend messages. This is a workaround imposed by the fact that almost all software and hardware music devices don't allow the use of Midi Tuning Standard (MTS).

Read more about this problem with MTS implementation in my article [Microtonality and the Struggle for Fretlessness in the Digital Age](#), published in the CTM Festival magazine 2019.

## **Why is Apotome a generative system?**

Generative systems have their pros and cons. One of the best things about them is that they can do things you normally wouldn't do if you were playing an instrument or humming an idea in your head.

Apotome is designed for exploration and experimentation, to help us “unlearn” and “untrain” our ears away from equal temperament and away from traditional rules of music making associated with different musical cultures.

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# HOW TO USE LEIMMA

Leimma Tutorial video → <https://vimeo.com/503475532>

## User Account

To get the most out of Leimma you should sign up for an account and sign in. This will allow you to save your work and access it with ease.

You can still use Leimma without an account, and save the URL of your Tunings and Subsets as → [bookmarks](#), but you won't be able to save anything for use within Apotome.

## 0: Select or Create a Tuning System

The homepage of Leimma allows you to Select or Create a tuning system.

Pressing [Select a Tuning System] will load the database from which you can choose from a variety of existing tunings that will be continuously updated.

Pressing [Create a Tuning System] will allow you to create your own.

## 1: Reference Pitch

Tuning is relative. To create, hear and play any tuning system, a reference pitch must be chosen to tune all the different divisions in relation to it. This reference pitch, or its octave equivalents, will be used as the 1:1 ratio or 0 cents division in the tuning system and all its associated subsets.

The modern standard reference pitch for 12-tone equal temperament is A4 = 440 Hz, but any note name can be used to equal any Hz value.

It is best practice to use the note name that will remain consistently mapped to the value of the 1:1 in your tuning system and subsets.

For example, if your tuning system uses A4 = 440 Hz as a reference pitch, but your subset maps the 1:1 or 0 cents division to G, and the A to another ratio or cents value, the note A4 will no longer have the frequency value of 440 Hz or its octave equivalents. It will be changed according to the ratio or cents value assigned to it.

In this scenario, it is best to map the note name A to the 1:1 or 0 cents division of the tuning. Keep in mind that the 1:1 division does not have to be the root of your subset. You can choose the root to be any note you have mapped.

Obviously also feel free to break the rules and do whatever you want, but it's good to know them. If you use → [Modal Transposition](#), then this guideline will be broken.

## 2: Create or Modify Divisions of the Octave

On this page, the octave is represented as a ruler. If you are creating your own tuning, you can input the details according to the information below. If you are working with an existing tuning, you can click on a division and change its value.

Tuning systems are usually defined in ratios or in accumulative cents values where by the number increases from one division to the other until it reaches the last division which is the closest to the value of the octave at 1200 cents.

### Add Ratios/Cents

Use this number box to enter your ratio or accumulative cents value.

### Slice the Octave/Mark the Ruler

Hover over the ruler and click wherever you want to place a division.

### Use Equal Divisions

This feature is coming soon.

### Adjusting the Reference Pitch

Should you wish to adjust the reference pitch, you can do so on this page.

### Import Scala Files

The [Scala file format](#) is extremely popular for tuning systems. You can import a Scala file here, but please double check it is an octave repeating tuning that you are importing, otherwise you will get inaccurate results.

Importing other tuning file formats such as AnaMark (\*.tun, \*.msf) will be implemented soon.

You can [→ export your Tunings and Subsets](#) as Scala files.

## 3: Mapping Subsets

On this page, the Tuning System ruler morphs into a wheel, to represent the cyclical nature of the tuning system i.e. that it is octave-repeating.

Mapping allows you to play up to 12 subdivisions from your tuning system at any time, by collating them into a subset.

You can save as many subsets as you like if you signed up for an account. Otherwise you can [save them as bookmarks](#).

## How to Map

Click on the lower half of the division segment to highlight the division, and then use your computer keyboard, or your MIDI keyboard to choose which note that division is mapped to.

## Changing the Root

The indication of the root does not affect anything in Leimma except the visual display, but in Apotome, you can [→ choose the probability of the root note being triggered](#).

If you want to change the root, simply drag the thin white marker to the relevant mapped division. Or select the division by clicking the bottom half of the segment and use the dropdown menu.

## Clear all mappings

A quick way to clear your current mapping and start again. This does not affect your saved Subsets.

## Solmization

Solmization is the selection of syllables used by different cultures to represent different note names. Such as:

Solfge: Do Re Mi Fa Sol La Si

North Indian Sargam: Sa Re Ga Ma Pa Dha Ni Sa

Javanese: Ji Ro Lu Pat Ma Nem Pi

All the Solmization names are connected to and start from the MIDI keyboard C or QWERTY keyboard A.

## Degree Roles

In Leimma the degree roles are merely symbolic for the purpose of learning, they do not affect the Subset in any way. But using them will allow access to the subtleties of your [→ subset in Apotome](#).

Each degree can be given a role of Primary or Secondary. Use primary roles for the essential degrees of the subset, and secondary for any degrees that are used to bring out different characteristics.

Once a division is defined as the Root, its role cannot be changed before a different division is defined as the Root instead.

## Modal Transposition

When using tuning systems that use equal divisions of the octave, transposing a subset to a different starting degree (to a different root) maintains the exact sounding melodic distance between each interval, regardless of whether the transposition is lower or higher.

When using unequal divisions of the octave, transposing the intervals that make up a subset yields far more experimental results.

You can do this in Leimma simply by clicking the upper segment of the division assigned as root, and turning the wheel. This will maintain the same interval relationships, but will start the subset and its mapping on a different degree, and will sound completely different.

## Playing Subsets

Once you have mapped your subset, you can now play it using your computer keyboard, the onscreen keyboard, or your MIDI keyboard.

When using a computer keyboard you can press the bottom left two letters to change the octave up or down.

## Subset Playback

Clicking the small play icon at the end of the root bar will playback the root and primary degrees of your subset in an ascending pattern that will give you an idea of what the subset sounds like modally.

## On-screen Keyboard

The onscreen keyboard serves as a simple tool to play, and see information about the subsets such as the mappings and the divisions.

## MIDI Input and Output

You can send and receive MIDI data to/from Leimma via hardware MIDI in/out or a virtual MIDI bus in/out.

This allows you to input MIDI information from a hardware device (MIDI Keyboard or sequencer) or a software device such as a DAW. Or output to your own hardware or software instruments and sample libraries.

By using Leimma as a bridge, you can also route MIDI in and out in any way you like.

To achieve accurate tuning over MIDI, Leimma sends out a Pitch Bend message on every note. We have also implemented MPE (MIDI Polyphonic Expression) as a MIDI output method.

For the tunings to render correctly, the pitch bend range on your external hardware or software instruments must be [→ calibrated](#) correctly. When using MPE, the default standard is 48 semitones.

## MPE (MIDI Polyphonic Expression)

You can output MIDI from Leimma using MPE to any MPE enabled software or hardware synthesiser. Simply select your [MIDI Output] and then select [MPE poly] in the MIDI channel dropdown menu.

MPE as an input is not yet supported.

For the tunings to render correctly, the pitch bend range on your external hardware or software instruments must be [→ calibrated](#) correctly. When using MPE, the default standard is 48 semitones.

## MIDI Calibration

If you are using any hardware or software devices outside of Leimma, you must make sure that Pitch Bend Range of the device, and the track that is controlling it, are the same.

We have created a simple method to help with the calibration from within Leimma, as opposed to making adjustments on your device.

When you have chosen your MIDI output, you will see a [Calibrate] button. Click the button to load the calibration for that track and instrument combination.

Use the loop to adjust Apotome's pitch bend range, so that the two notes you hear are in exact unison.

If you are uncertain, please use a tuner to double check.

## Saving/Sharing using Bookmarks

You can save or share an individual Tuning System, or the Tuning System and its Subset Mapping, simply by bookmarking or copy/pasting the URL of Page 2 (ruler view) or Page 3 (wheel view) after you have completed your mapping.

For Tunings and Subsets within the database, simply load them and bookmark, share or copy/paste the URL.

## Saving to My Tunings

If you signed up for an account, you can save Tunings and Subsets to the My Tunings category. These will also show up under the same category name in Apotome as well.

## Exporting Tunings & Subsets

The [Scala file format](#) is extremely popular for tuning systems. You can export your Tuning or Subset from Leimma as a Scala file for use in other software or hardware devices.

Simply click on [Export Scala File] in the top right.

On Page 2 of Leimma (the tuning ruler/bar), you will only be able to export the Tuning system.

On Page 3 of Leimma (the wheel), you can export either the Tuning system or the Subset.

Leimma only works with Octave Repeating tuning systems and subsets.

**IMPORTANT:** To make sure your Subset is exported and playable with the same mapping you have chosen in Leimma, be sure to have at least 12 divisions in your tuning system and that all 12 chromatic notes/MIDI Keyboard keys are mapped, even if you don't plan on using all of them.

This will ensure that the pitches you do want to use will be accessible via the same notes/MIDI keyboard keys (C, C# etc...) that you have assigned in Leimma.

## Exporting Scala Subsets Best Practice Guidelines

If you want to export your Subset as a Scala file (for use with external software or hardware) in the same way you have mapped it in Leimma, you must map all 12 chromatic notes/MIDI Keyboard keys. This is to make sure that the divisions correspond to the same notes on piano roll or the same notes on your MIDI Keyboard.

If mapping is not an issue for you, then you can ignore this.

Example: You want to export one of the [African Balafon Tuning Subsets](#). This tuning has only seven divisions/pitch classes, and they are mapped to the white keys starting from C.

The trick would be to go back to Page 2 using the breadcrumbs in the bottom left, and manually insert five more divisions. For ease of identification and use, it's recommended that you insert equal temperament values.

Then move forward to Page 3 and map them to the unused black keys.

Original Divisions and Mapping:

C	C#	D	E $\flat$	E	F	F#	G	A $\flat$	A	B $\flat$	B
0 (1:1)		187		356	526		672		856		985

Modified Divisions and Mapping:

C	C#	D	E $\flat$	E	F	F#	G	A $\flat$	A	B $\flat$	B
0 (1:1)	100	187	300	356	526	600	672	800	856	1000	985

You'll notice that the last two pitch classes are not in accurate ascending order. This is because the 985 value should be mapped to B $\flat$  if we were to use equal temperament as a guide, but that is not necessary.

Regardless, it makes more logical sense to use the equal temperament values as placeholders, because it will keep things simple and clear.

# HOW TO USE APOTOME

Apotome tutorial video → <https://vimeo.com/503451447>

Please check the → [Simple Apotome Tutorial](#) for a text based overview.

## User Account

To get the most out of Apotome you should sign up for an account and sign in. This will allow you to save your work and access and submit sessions to the community pool.

You can still use Apotome without an account, but you won't be able to save anything.

## Sessions and Snapshots

On the right hand side you will see a small button called [Sessions], click it to open that panel and then [Create New Session].

Think of a Session as a track or a composition. In your profile you will be able to save multiple Sessions.

Each Session can have multiple Snapshots.

A Snapshot is a capture of all the settings of all Apotome tracks and the master tempo and time signature (except the MIDI SYNC SETTINGS) at the time of capture.

By capturing and saving different Snapshots, you can create an arrangement for that Session.

This is incredibly powerful because it allows you to create arrangements that can change completely from Snapshot to Snapshot... different tempos, different number of tracks, different settings, different Web Synths, different sounds and most importantly different Tunings and Subsets!

As you are working, you can [Capture Current and Overwrite] which will replace that Snapshot with everything you can see in Apotome at that time.

To save a new Snapshot, click [Capture Current as New Snapshot].

## Saving Your Session

Be sure to regularly save your session by clicking [Save Session] at the bottom of the Snapshots list.

## Creating Arrangements

Snapshots can be set up to be controlled manually or autonomously.

This is done by setting the [Duration] in each [Snapshot]

If you want to control when to change between Snapshots, keep the Duration setting to Manual.

If you want to automate the change from one section to the next, you can define the amount by Min and Max number of Time or Bars.

If you want the length to be fixed, set the same amount in both Min and Max. If you want Apotome to randomly choose a length, set the Min and Max to the range that you'd like the value to be within.

## Session Length and Looping

If you want your Session to run all the Snapshots autonomously, and you want it to have a predetermined length, click the [Looped] switch in the Session header.

This will set your Session to play through all the Snapshots autonomously according to your Min and Max values for each section. It will then Loop by going back to the first Snapshot after the last, until it reaches the predetermined length of the entire Session.

The Session length can be set as Total Min Duration and Total Max Duration.

If you want the Session length to be fixed, set the same amount in both Min and Max. If you want Apotome to randomly choose a length, set the Min and Max to the range that you'd like the value to be within.

## End with Fade Out

If you want the Session to fade out at the end instead of having a hard stop (stop all midi), click the [End with Fade Out] switch.

## Session Performance or Playback

Once you're ready to playback or perform your Session, click on the arrow next to Edit Session or press the [Close Session] button at the bottom of the Snapshots list.

Then press [Play] on the Session you want to playback or perform.

This will start the generative playback and will run according to the settings that you have decided on such as Snapshot transitions and Session length.

During playback, you can still change any and all parameters. And you can switch from Snapshot to Snapshot just by clicking on them.

Once clicked each Snapshot will load and run according to its own settings.

## Community Sessions

Community Sessions are a pool of Sessions submitted by the users of Apotome. By clicking play, you will be able to listen to and see that session running whilst being able to manipulate the parameters.

## Submit to Community

We will be encouraging users to submit their Sessions into a Community pool.

When a Session is submitted, it will be checked by a moderator to make sure it is set up correctly for autonomous playback is set up correctly, before approving its inclusion in the Community pool. Once it is approved, it will show up under [Community Sessions] and be included in the live stream.

Even when a Session has been approved and is available in the Community pool, you still have the ability to [Withdraw] it.

## Booking a live performance as part of CTM 2021

Throughout CTM Festival 2021 anyone, world-wide, can sign-up for a predetermined time-slot and have the chance »perform« Apotome live by manipulating its parameters, whilst the result is broadcast in real-time via both CTM Cyberia and and on the website.

By signing up, you can book a 30-minute time slot for your performance and have time to prepare and rehearse your material here in the Apotome Studio prior to your performance.

Upon booking you will receive an email with a unique link you must use to access the performance area. You cannot perform from Apotome Studio. The performance area uses the same interface that you see here in Apotome Studio and will contain all your saved Sessions and Snapshots.

The same booking confirmation email will contain a link at the bottom for you to cancel your performance if you change your mind. Please be considerate of others and cancel your booking if you cannot make it or decide not to do it.

- Your performance will be live streamed on the web and within CTM Cyberia only, it will not be recorded or archived in any way.

- In advance of your performance, your username, twitter handle and twitter profile link (if provided) will be visible alongside your performance date and time in the schedule on the website and in CTM Cyberia.
  - During your performance, your username, twitter handle and twitter profile link (if provided), country, the name of your Session and names of all the tunings and subsets you use in will be publicly visible.
  - Please take time to prepare and rehearse so that your performance is a meaningful and fun experience.
  - There will be no paid compensation or remuneration for your performance. This project is non-commercial, free to use and nothing you create in it will be exploited in any way.
-

# GLOBAL PARAMETERS

## Tempo

Set your desired tempo using the slider. If you want to use decimals, e.g. 120.56 bpm, you can type them into the number box.

## Global Time Signature

Global time signatures can be used in two ways, simple or additive.

The simple method is to simply type in the upper numeral and select the lower numeral from the drop down menu, e.g. 4/4.

The additive method allows you to type the upper numeral as beat groupings,

e.g. 2+2 / 4

or 3+3+1 / 8.

Both the simple and additive methods can be used to activate [→ accents](#) during the generative playback. Simple time signatures can activate an accent on the first beat of every bar. Additive time signatures can activate an accent on the first beat of each grouping.

For example:

4 / 4 = 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4

2+2 / 4 = 1 2 3 4 1 2 3 4 1 2 3 4

## Global Start / Stop

This is the global transport control for Apotome. It runs separately from the [→ track based start/stop](#) function.

## Re-Sync Tracks

Sometimes whilst adjusting various parameters, your tracks can go out of sync. Clicking [Re-Sync Tracks] will start them all again together without interrupting generation/playback.

## MIDI Panic

This button forces all currently playing midi notes to stop by sending an All Notes Off midi message to all tracks, but it does not stop the generation/playback. It is useful to get rid of hung midi notes without interrupting your session.

## Settings

Global settings for Apotome including [→MIDI Clock Out](#).

## MIDI Clock Out

Apotome can be used to sync hardware devices or software by going to the global [→ settings](#) button and choosing which Midi Output to send the Midi Sync message to.

Note:

- You may need to adjust the Midi Clock offset within your DAW or hardware device in order to get everything running in time.
  - You will also need to set the correct time signature in your DAW or on your hardware device manually for them to run according to the time signature and bar lengths in Apotome
-

# TRACK PARAMETERS

## Start/Stop Track

The track based start/stop states work independently of the [→ global start/stop](#) state. This allows the system to run whilst allowing you more control over what is playing when. To start all track playing when the global start/stop is activated, make sure they are all in their [Start] state.

Newly duplicated tracks will not auto-start during playback, nor start with global playback, until you click their individual [Start/Stop] button.

## Randomise

Click on [Randomise] to have Apotome select a random Tuning and Subset plus randomise the tracks parameters.

In order to maintain a meaningful result this Randomise function will use the following fixed rules:

- Only Tonic and Primary subset role degree weights
- Note Delay Min always at 0%
- Articulation Range always set Min to 0% and Max to 100%
- Velocity Range always set Min to 50% and Max to 100%

Everything else will be randomly generated.

## Mute and Solo Track

Use [M] to mute and [S] to solo the track during playback.

## Duplicate and Delete Track

Use the [+ ] icon to duplicate a track and the [x] icon to delete a track.

Newly duplicated tracks will not auto-start during playback, nor start with global playback until you click their track based Start/Stop button.

Track 1 cannot be deleted.

If duplicating a track is disabled, then you must either delete some tracks, or check the number of voices being used in your OBXD patches under GLOBAL. Reduce the

number of voices used in the preset and you will be able to add more tracks. This is due to server limitations during the CTM live stream.

## Add New Track

Use the [+] icon to create a new track.

During the CTM Festival period there is a limit of 8 tracks, and a limit on the number of voices. This is due to the restrictions of the live 24/7 generative stream.

The OBXD synth uses multiple voices for some presets. Reduce the number of voices and you will be able to add more tracks.

Once the festival is over and the live stream is finished, these restrictions will be lifted.

## Follow Track 1

On every Track *except* Track 1, you will find multiple switches named [Follow Track 1]. This allows the control of multiple parameters across different tracks *from* Track 1.

It is particularly powerful for changing between tunings or subsets on multiple tracks.

You can do this by just selecting a new Tuning System and Subset from the database and drop down menu, or by selecting one from those stored in your [→ Favourite Tunings](#) list.

## Tuning & Subset

For a track to be active, a tuning system and a subset must be selected.

Click [Select] and choose a tuning system and one of its subsets from the database. Then click [Select Subset] to choose a subset.

Click on the name of the subset to open it directly in [→ Leimma](#).

If you want to create your own tuning system and subsets, or subsets from an existing tuning system, you must use [→ Leimma](#).

## Reference Pitch

To create, hear and play any tuning system, a reference pitch must be chosen to tune all the different divisions in relation to it. This, or its octave equivalents, will be used as the 1:1 ratio in all the subsets of that tuning system.

When you have selected a tuning system, it will load with its associated reference pitch. You can edit it to suit your preferences by choosing the MIDI note name e.g. [A4] with the closest frequency (Hz) you want from the dropdown menu and adjust the frequency to your liking, e.g. B4 = 396 Hz (random example).

For more information on best practice please see [→ Reference Pitch](#) in the section on Leimma.

If you are using different tuning systems on different tracks, they may sound better if they're all set to the same reference pitch, even if the subsets use different divisions as their root. It's worth a try.

## Subset Role / Degree Weights

Subsets (scales/modes) can be used for melodic generation in Apotome in two main ways:

- [Use Role Weights] to adjust the weighting according to the roles that are assigned to each degree of a subset.
- [Use Degree Weights] to adjust the weighting of the individual degrees.

You can switch between both options without losing their values.

All subsets created in Leimma and available in Apotome will have a role assigned to each degree: Primary, Secondary or None.

To get more controlled results please see the [→ Simple Tutorial](#) section of this guide.

## Favourite Tunings

You can save your favourite Tuning with its Reference Pitch, Subset and Scale Degrees Weighting into your own list.

In Track 1, choose a tuning system and subset, and set its Scale Roles/Degrees Weighting to your liking. Then click [Favourites].

Here you'll be able to give your preset a name and save it for easy access.

If you use [→ Follow Track 1](#) on multiple tracks, you can change all their tunings in one click by choosing a new one from your Favourite Tunings List, or by selecting a new one from the database and drop down menu.

## Rests

Regardless of whether you choose Role Weights or Degree Weights, you will always be able to adjust the probability of rests being triggered.

The rests slider is independent in both options allowing you to switch between them whilst keeping a different value for the rests in each one.

## Allowed Melodic Intervals

These radio buttons allow you to define what melodic intervals can be used during the generative playback or performance.

[0] allows the next generated note to be the same as the last note generated

[1] allows the next generated note to be a distance of one step from the last note generated

[2] allows the next generated note to be a distance of two steps from the last note generated

Etc...etc.. etc...

[8ve] allows the next generated note to be a distance of one octave from the last note generated

## Force polyphony

Any tracks that have this switched on will be forced to never play the same note in the same octave at the same time i.e. anything other than unison.

This can be used to have a melodically richer and more experimental generation, whilst also allowing the generation of chords across multiple voices (tracks).

## Octave Weights

These sliders determine the probability of the chosen octaves to be used for generation. The octaves must be selected adjacent to each other. If there is a gap i.e. you have only selected Octaves 3 and 5 (without Octave 4), then Apotome will be stuck within whichever octave is generated first.

## Override Time Signature

Each track can have its own independent time signature, regardless of the [→ Global Time Signature](#). When [Override Time Signature] is turned on, the time signature can be defined in the same way as with the Global Time Signature i.e. simple or additive.

The simple method is to simply type in the upper numeral and select the lower numeral from the drop down menu, e.g. 4/4.

The additive method allows you to type the upper numeral as beat groupings e.g. 2+2 / 4 or 3+3+1 / 8.

Both the simple and additive methods can be used to activate [→ accents](#) during the generative playback. Simple time signatures can activate an accent on the first beat of every bar. Additive time signatures can activate an accent on the first beat of each grouping.

For example:

4 / 4 = 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4

2+2 / 4 = 1 2 3 4 1 2 3 4 1 2 3 4

## Use Accents

When this is turned on, accents of 30% velocity greater than the velocity of the generated note will be used at the beginning of each bar or beat grouping according to the [→ Global](#) or [→ Track](#) Time Signature

## Beat Division Weights

Rhythmic values of notes can be generated by Apotome in two ways, by using standard beat divisions or [→ euclidean rhythms](#).

### Shorter / Longer

When using standard beat divisions, the sliders determine the amount of probability that a beat division will be generated. These beat divisions are grouped as [Shorter] or [Longer].

[Shorter] beat divisions range from 16th note ( $\frac{1}{16}$ ) to a whole note (1).

$$1 = \text{whole note} = 4 \times \frac{1}{4}\text{-notes} = 8 \times \frac{1}{8}\text{-notes} = 16 \times \frac{1}{16}\text{-notes}$$

All the other values  $\frac{1}{3} \frac{1}{5} \frac{1}{6} \frac{1}{7} \frac{1}{9} \frac{1}{10} \frac{1}{11} \frac{1}{12} \frac{1}{13} \frac{1}{14} \frac{1}{15}$  are different types of tuplets

[Longer] beat divisions range from 1 to 16 and are multiples of a whole note i.e. 16 = 16 whole notes.

## Allow rests

These buttons allow you to define whether a rest of the particular value is allowed or not.

For example: if you have chosen to use only  $\frac{1}{4}$  and  $\frac{1}{8}$  and  $\frac{1}{16}$  values, you might want not want any rests with the values  $\frac{1}{8}$  or  $\frac{1}{16}$  in order to avoid jarring syncopations. In this case you would deselect the [Allow Rests] buttons under those values.

## Force tuplets

This switch will force the grouping of tuplets i.e. whenever a tuplet of the particular value is selected by Apotome, it will always be generated as a group according to the following rules:

$\frac{1}{3}$  will be generated as a group of  $3 \times \frac{1}{3}$

$\frac{1}{5}$  will be generated as a group of  $5 \times \frac{1}{5}$

$\frac{1}{6}$  will be generated as a group of  $3 \times \frac{1}{6}$

$\frac{1}{7}$  is a prime number and will be generated as a group of  $7 \times \frac{1}{7}$

$\frac{1}{9}$  will be generated as a group of  $3 \times \frac{1}{9}$

$\frac{1}{10}$  will be generated as a group of  $5 \times \frac{1}{10}$

$\frac{1}{11}$  is a prime number and will be generated as a group of  $11 \times \frac{1}{11}$

$\frac{1}{12}$  will be generated as a group of  $3 \times \frac{1}{12}$

$\frac{1}{13}$  is a prime number and will be generated as a group of  $13 \times \frac{1}{13}$

$\frac{1}{14}$  will be generated as a group of  $7 \times \frac{1}{14}$

$\frac{1}{15}$  will be generated as a group of  $5 \times \frac{1}{15}$

## Euclidean Rhythm Generator

Selecting [Euclidean] under Beat Division Weights activates the Euclidean rhythm generator for that track. Melodic material will continue to be generated according to

the other settings but the rhythmic value of it will be determined by the Euclidean rhythm generator settings.

## Loop

This looper acts as a device to capture the previous 1, 2, 3 or 4 bars of generated material and loop them. The length of the bar is determined by the [→ Global](#) or [→ Track](#) Time Signature.

It is designed for use during live performance and its settings will not be saved within [→ Snapshots](#). The buttons are automatically mapped to different keys on the QWERTY keyboard so that they can be used during performance.

Press a key or click once to latch and again to remove.

NOTE: Material captured in the Loops will not be saved in your snapshot

## Note Delay

Adds a random note delay to the defined range of values between 0 and 100 ms. This helps give the generative playback a more natural feel.

## Note Length

The length of generated notes can be controlled in two ways, by defining a [Range] or specifying fixed [Lengths] per Beat Division.

### Range

Defines the minimum and maximum range within which a random length will be selected, from very short Staccato to full note length Legato.

### Shorter / Longer

This follows the same principle as the [→ Beat Division Weights](#) and allows for fixed note lengths per Beat Division based on the sliders.

Slider at 100% = full note length Legato.

Slider at 0% = very short Staccato.

## Velocity Range

Defines the range of random velocity per note.

## Instrument

Apotome can be used with a small selection of built-in web synth modules or set to output MIDI information.

### Basic Synth

A very basic web synth with a choice of four oscillator waveforms: Sine, Sawtooth, Triangle, Square, an ADSR envelope and a Filter with cutoff and resonance controls.

### Karplus-Strong

A basic web synth based on Karplus-Strong algorithm which allows for digital synthesis of plucked-string and drum timbres.

### OBXD

OBXD is based on the OB-X synthesizer from Oberheim released in 1979.

OBXD is the work of plugin developer 2Dat. It is a powerful virtual analog synthesizer emulating many of the fat and lush sounds associated with the original instrument. Included are many banks and presets from the open source community.

Web Audio Module implementation by Jari Kleimola <https://wam.fm>

### DEXED

DEXED is an emulation of the DX7 synthesizer produced by Yamaha in the 1980's which utilized FM synthesis (Frequency Modulation). The DX7 was one of the most popular synths of its time.

The original DEXED was developed by Pascal Gauthier of Digital Surburban and released as an extremely popular free VST.

Web Audio Module implementation by Jari Kleimola <https://wam.fm>

### Yoshimi

Yoshimi is a software audio synthesizer, originally forked from ZynAddSubFX. This browser version has no controls and only the bundled presets.

Web Audio Module implementation by Jari Kleimola <https://wam.fm>

## MIDI Out

Apotome can send MIDI data from any track to any virtual MIDI bus or physical MIDI output connected to your computer, including [→ MIDI Clock](#). This allows you to use your own hardware or software instruments and sample libraries.

Each of Apotome's tracks is monophonic and therefore only needs one midi channel.

To achieve accurate tunings over MIDI, Apotome sends out a Pitch Bend message on every note. It also works with [→ MPE](#) compatible software or hardware instruments.

**IMPORTANT:** For the tunings to render correctly, the pitch bend range on your external hardware or software instruments must be [→ calibrated](#) correctly.

## MPE (MIDI Polyphonic Expression)

You can output MIDI from Apotome using MPE to any MPE enabled software or hardware. Simply select your [MIDI Output] and then select [MPE poly] in the MIDI channel dropdown menu.

For the tunings to render correctly, the pitch bend range on your external hardware or software instruments must be [→ calibrated](#) correctly. When using MPE, the default standard is 48 semitones.

## MIDI Pitch Bend Calibration

If you are using any hardware or software synths outside of Apotome, you must make sure that Pitch Bend Range of the synth, and the track that is controlling it, are the same.

We have created a simple method to help with the calibration from within Apotome, as opposed to making adjustments on your synth.

When you have chosen MIDI Out as an instrument, you will see a [Calibrate] button. Click the button to load the calibration for that track and instrument combination.

Use the loop to adjust Apotome's pitch bend range, so that the two notes you hear are in exact unison.

## LFOs

Each Track in Apotome has four LFOS with different shapes that can be mapped to specific parameters in each Track [→ Mixer](#) section, and each [→ Instrument](#).

## Shape

Each LFO has a choice of four waveshapes: Sine, Square, Ramp Up, Ramp Down and Random (Sample & Hold).

## Target

The [Target] options for each LFO will change depending on the [→ Instrument](#) that is selected. The Mixer targets: volume, pan, send 1, send 2, are available for all instruments except [MIDI Out], for obvious reasons.

When using [MIDI Out], the LFOs can be mapped to a selection of MIDI CC (continuous controller) numbers.

## Rate and Amount

The speed [Rate] and amount of modulation [Amount] .

## Retrigger

Turn on [Retrigger] to reset the phase of the LFO waveform every time a new note is generated.

## Mixer

When using the internal web synths, the Mixer section will be available on each track.

## Volume, Pan, Reverb and Delay Sends

Self explanatory, no?

## Simple Apotome Tutorial

Generative or algorithmic based music systems can often create results that unintentionally sound “messy” or “random”. This is a great trait, but learning how to limit or control the parameters is equally powerful.

More often than not, it’s not enough to just simply press start and hope that the system will create something enjoyable to experience—even more relevant when dealing with tunings and musical systems from cultures you may not be familiar with.

This is where issues of bias come in when dealing with systems that employ a lot of controlling procedures “under the hood”. Apotome essentially allows you to build your own algorithms by adjusting its various parameters.

If you are new to these kinds of processes, try the following tutorial:

- Use only Track 1
- Set Master Tempo to 100bpm and Master Time Signature to 4/4
- Load a tuning system and a subset of your choice.
- Set the [Subset Role Weights] to Tonic only at 100%
- Set [Allowed Melodic Intervals] to 0, 1 and 2 only
- Set the [Octave Weights] to 3 at 100% only
- Set the [Beat Division Weights] to  $\frac{1}{8}$  at 100% only
- Set the [Instrument] to Basic Synth, using a Triangle waveform
- Press start and whilst listening to the tonic of the subset, slowly raise the Primary [Subset Role Weight] to 100%, you should hear the subset start to present itself modally.
- Slowly raise the Secondary slider to hear if this Subset’s mapping includes any secondary notes.
- Try raising the “None” slider to hear notes not used in the Subset.
- Add Rests.
- Try adding more [Allowed Melodic Intervals] and listen to how the melody starts to change as the interval jumps generated become more varied.
- Add more [Octave Weights] making sure they are all in sequence - having gaps won’t let the generated notes jump unless you have [8ve] activated.
- Play with different beat divisions or the euclidean rhythms patterns to try different rhythmic combinations. Don’t forget to change the tempo to something that feels better if necessary.

- Change the sound by choosing a different instrument and trying out different presets, or making your own.
- Continue refining until you've found something you like.

Duplicate the track you're working on and activate [→ Force Polyphony](#). Set both tracks to only one octave of your choice to hear polyphonic combinations.

## FAQ

### Why can't I hear anything?

Double check that a [→ Loop](#) hasn't been accidentally activated by a QWERTY key.

### How do I change the Tuning System and/or Subset across multiple tracks at once?

Activate [→ Follow Track 1](#) on all tracks you want to control, and make the change on Track 1 by using the database and dropdown menu, or by using your [→ Favourite Tunings](#) list.

### Why can't I hear any tracks other than Track 1?

Make sure you [→ press start](#) on the individual tracks.

All tracks are created with their state set to stop so that you can control which tracks are playing when without any surprises.

### Why can't I add more tracks?

During the CTM Festival period there is a limit of 8 tracks, and a limit on the number of voices. This is due to the restrictions of the live 24/7 generative stream.

The OBXD synth uses multiple voices for some presets. Reduce the number of voices and you will be able to add more tracks.

Once the festival is over and the live stream is finished, these restrictions will be lifted.

### Can I use Leimma with my DAW?

Yes! For this you need to use a virtual MIDI bus.

Send midi from your DAW track to your virtual MIDI bus Ch x. Set Leimma MIDI input for the same bus and channel. Set Leimma MIDI output for the a different bus and channel. Create a new track in your DAW and set it to receive the same that Leimma is outputting to.

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## Answers to the [tuning exercise from p. 14](#)

1:1	Add one third to previous	Remove one third from previous	Add one third to previous	Remove one third from previous
81mm	108mm	72mm	96mm	64mm
1:1	Fourth lower than previous	Fifth higher than previous	Fourth lower than previous	Fifth higher than previous

If you got these right, then you have successfully figured out the lengths for creating a set of panpipes tuned to the ancient Chinese pentatonic tuning attributed to Huang-Ti, the Yellow Emperor from around 2967 BC but first recorded by Kuan-tzŭ around 300 BC ([Nakaseko 1957:149](#)).

If we now put them in order of length, we see that although we started with 1:1 as our reference, we now have two notes below it, meaning that our Subset will actually start with a sound that is lower in frequency than where we started.

		1:1		
108mm	96mm	81mm	72mm	64mm

To resolve this we can cut the two pipes below the 1:1 in half to raise them up into the next octave, which would start on 1:1, the reference pitch we started with. Now we have a tuning system that has all its divisions within the same octave.

1:1			108mm/2	96mm/2
81mm	72mm	64mm	54mm	48mm

Next we can write out the ratios and reduce them to simpler numbers, and we can use them to tune or create other instruments that would sound the same intervals and even the same pitches/frequencies if the 1:1 were tuned the same on both.

1:1	81:72	81:64	81:54	81:48
1:1	9:8	81:64	3:2	27:16

To end, you can input these ratios into Leimma and hear what they sound like!