

## CHAPTER 4

# Something moves

*‘Nothing happens until something moves.’*

—Albert Einstein

Although it is always interesting to know what historical sources have to say, and what our present colleagues think, about matters concerning tone production (see Chapters 2 and 3), there is one aspect that we can only find out on our own: how can our own instrument sound good to us according to our own taste? This is not a matter governed by historical instruments but by our own ability to treat the modern instrument at hand, and make it sound in a manner that is not only pleasing to us but also projects well in a certain space. The lute is known as a soft instrument, but with the right treatment — i.e. playing technique, placement of the performer, instrument selection, instrument set-up and choice of music — it can in fact be heard easily in surprisingly different contexts, even without using microphones (which I return to in Chapter 6). The present chapter will take a more physical turn than other chapters in this book, because the very foundation of a sounding instrument has to do with its construction and performance, i.e. its physics. Understanding the physics of an instrument is the key to understanding cause and effect, which in turn provides a more empirical foundation for conceptualising sound; it also provides us with the necessary tools for self-development and problem solving. To separate topics for the sake of clarity, I will leave psychological perspectives on how we perceive, like and develop tone production until Chapter 5, where the physical aspects presented here will be compared

to the historical (Chapter 2) and modern (Chapter 3) directions already presented.<sup>1</sup>

Being a musician is, in part, being an artist of perception and physics. When we play a tone, we initiate a chain of reactions among air particles (to take a normal musical performance as an example) that a listener perceives and feels in a certain way. In order to understand sound and tone production, it is vital to understand that there is much more to sound than just air waves being produced to create music; in fact, ‘soundwaves’ is just a figure of speech. To me, at least, there is indeed a greater poetry in physics than just a transportation of sound from performer to listener; understanding the nature of sound makes that ‘transportation between A and B’ something dynamic, (partly) controllable and, in fact, something living. It can become part of the instrument and part of the performer, who can actively use physical principles to create music that mediates what they as performers intend to mediate. By understanding how sound actually works, the lutenist is left with the opportunity to make informed decisions in their tone production and form their own concept of ‘good’ sound — ‘this sounds like this because ...’ or ‘to get the sound I want I have to do this,’ for instance. Deep knowledge of how things work can alter tone production to being something more than a habit; it can become a form of design or sculpting. Informed play, as I presented earlier, is thus more than simply reading sources and literature; it is also knowing what you are working with, how to affect the sound and how it develops over time. Furthermore, it helps to better understand sound biologically, i.e. as something developing over time, perceived as the sum of all its actions and reactions. The physics of lute sound is very concrete, very definable and therefore exemplifies the biological development of sound, before we, in later chapters, introduce more subjective concepts, such as psychological perspectives and sound recording, as well as drawing lines back to past chapters.

---

<sup>1</sup> For those interested in a historical discourse on the development and history of the lute; see Smith, D.A., *A History of the Lute from Antiquity to the Renaissance* (Canada: The Lute Society of America, 2002).

## Sound behaviour as foundation for conceptualising tone production

Understanding how lute instruments, or any other instruments for that matter, produce sound, requires a basic understanding of the physics and mathematics of sound development and propagation. In this section, I will focus on basic sound physics, addressing some fundamental features which will serve as the starting point for later discussions in this chapter.

Although sound is often represented using waveforms, it is vital to understand that sound is not actually propagated in waves in the traditional sense, often represented by a line going up and down around a centre line in an illustration; this is merely a mathematical way of describing air behaviour in terms of pressure changes over time. To fully understand sound propagation we must start elsewhere, outside the realms of mathematical representations and within the realms of relationships. The air surrounding us is full of small particles; without particles, we would find ourselves living in a vacuum. To put it simply, each individual particle has its natural, preferred place in a three-dimensional space. When a tree falls, creating a loud noise, it displaces the air particles, forcing them to leave their preferred space. When displaced, they get 'homesick' (figuratively) and try to go back home with such a force that they go too far the other way, and so it continues in an oscillating manner with less force each time (due to friction, etc.) until the air particles stand still in their resting place. This is, of course, a figurative manner of describing the process. When only considering one single particle the concept is easy enough to understand; it is almost like bungee jumping. But when that single particle moves, it collides with other particles and a complex chain of reactions is set in motion; hence the analogy of relationships, because everything happens as cause and effect, where everything depends on and relates to each other. Already here, then, we can perceive the biology perspective since each particle development creates actions and reactions that, in sum, produce complex air particle movements that we, through our auditory systems, perceive as sound. Indeed, this cause and effect is so powerful that it is also perceivable in silence. Consider, on one hand, the discomfort we perceive when there is no sound at all (such as in Microsoft's silent chamber), and on the other hand, deaf composers being able to experience music through vibrations.

The concept of sound is both something very concretised (through physics) and abstract (through cognitive and metacognitive perspectives), and it relates so strongly to its opposite, silence, that its impressive impact is inevitable whether it is 'there or not.'

We can speak of two important sound features: firstly, the force, i.e. how far away from 'home' the particles are (its amplitude); and secondly, how many times per second they move back and forth (its frequency). Starting with amplitude, the sound pressure level can be measured using the traditional unit for pressure, namely pascals (Pa). The human auditory system can normally perceive sounds starting at a level of approximately 0.00002 Pa ranging up to 100 Pa, where our hearing begins to become seriously impaired. A measuring scale between 0.00002 and 100 naturally presents difficulties in practise, due to the vast amount of levels in-between. To make this range more convenient and easier to handle, it is normal practice to employ a mathematical approach called logarithms, employing the decibel unit (dB) rather than pascals. The basic principle of logarithms serves sound physics very well, in that it makes the range between 0.00002 Pa to 100 Pa more manageable and also better represents our perception of amplitude. Basically, in logarithms, what we are asking is how many of the same number we need to multiply to reach another number. For instance,  $2 \times 2 \times 2 = 8$ , suggesting that we need to multiply three 2s to reach 8. This can be expressed as  $\text{Log}_{20}(8) = 3$ , where the number in brackets represents the number we wish to reach, and where the number following the Log explains what base we are using. The power of logarithms to treat large ranges of data is quickly evident if we use 20 as a base ( $\text{Log}_{20}(x) = y$ ):

$$\text{Log}_{20}(20) = 1$$

$$\text{Log}_{20}(400) = 2$$

$$\text{Log}_{20}(8,000) = 3$$

$$\text{Log}_{20}(160,000) = 4$$

$$\text{Log}_{20}(3,200,000) = 5$$

$$\text{Log}_{20}(64,000,000) = 6$$

$$\text{Log}_{20}(1,280,000,000) = 7$$

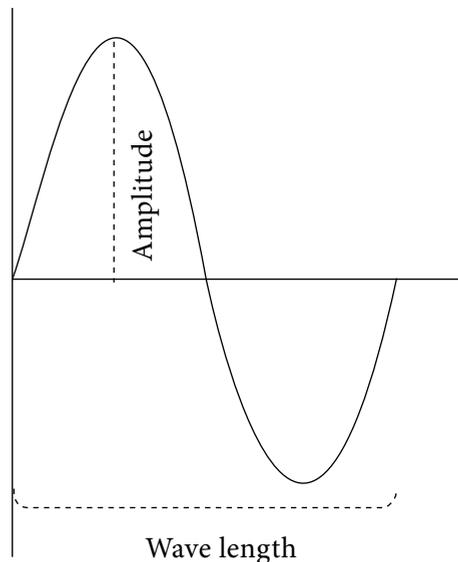
$$\text{Log}_{20}(25,600,000,000) = 8$$

$$\text{Log}_{20}(512,000,000,000) = 9$$

$$\text{Log}_{20}(10,240,000,000,000) = 10$$

As seen above, we can express a range of values stretching from 20 to 10,240,000,000,000 using only 10 numbers. If we say that 0.00002 Pa is 0 dB, we will find that 100 Pa is 133.97 ... dB, which is an easier range to deal with.

There is a good reason why I talk about logarithms, pascals and decibels in a book treating the lute. This is because understanding the difference between linear and logarithmic thinking provides the entire foundation for how we work with sound, how it is represented in illustrations and (later in Chapter 6) how we can use sonic features to sculpt our tone production throughout a music-production context, ranging from live performances to recording sessions. This is where the traditional, mathematical representation (i.e. Fast Fourier Transform or FFT) of sound actually becomes valid, because it describes the amplitude's development over time (see Fig. 4.1 below). Returning to the analogy above, the centre line represents 'home', movement above the centre line represents positive pressure, which is when the air particles are displaced by the above-mentioned tree, and movement below the centre line represents negative pressure, where the particles wanting to go 'home' go too far. The FFT graph enables us to view sound development over time, and it is easy to see where the popular expression of soundwaves stems from.

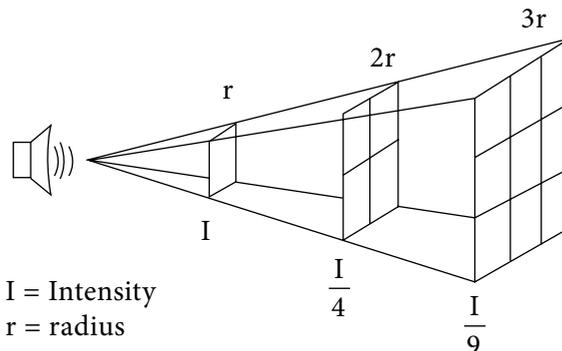


**Figure 4.1.** A Fast Fourier Transform showing air-particle movement over time.

Shifting focus to frequency, the distance from one positive peak to the following positive peak is called one wave length, period, or full cycle (usually described in mathematics as  $\lambda$ ; see Fig. 4.1 above). Similarly, the distance between a negative peak to the following negative peak is also one wave length. Simplified, one can say that a cycle is the sum of both one positive and one negative movement. The number of full cycles per second determines the frequency of a sound, that is how ‘high’ or ‘low’ we perceive them to be. A tone of 15,000 Hz, or 15 kHz, for instance, means that the sound reaches 15,000 full cycles per second; equally 10 Hz means 10 full cycles per second.

But there is much more to sound than the two-dimensional aspect of frequency and amplitude represented by the FFT graph. Sound does not propagate directionally, like a laser beam, but rather hemispherically (see Fig. 4.2 below). This means, in practise, that the further away from the sound source the chain of reactions between air particles moves, the more space the same air particles have to function within, ultimately resulting in less power; the air particles a sound meets also provide friction to slow down the movement. In sum, this means that amplitude decreases depending on the distance from the sound source (a fact that you do not have to be a physicist to experience in real life).

In fact, there is a logic to this decrease of amplitude over distance that can be formulated as double the distance equals minus 6 dB ( $2 \times d = -6\text{dB}$ ). Changing listening position from 16 to 8 metres distance produces the same amplitude increase (in decibels) as from 4 to 2 centimetres.



**Figure 4.2.** Illustration of how sounds propagates hemispherically.

This, in turn, means that one will experience less difference in amplitude when moving around far away from the instrument than if having the ear moving around right next to the soundhole. Conceptually, this is important when discussing lute sound production because it gives us points of departure to better understand lute sound propagation over distance and, together with frequency and amplitude, we are in fact given the tools to talk about physical processes and use a common language to further develop the biological cause and effect phenomena that sound propagation really is.

## Sound propagation and lute construction

It may be easily forgotten that technology does not only imply objects with electrical cords. The lute itself is a form of technology, and the lute sound as a concept begins already at the level of the lute instrument as a physical entity. This means that choosing a certain lute is also to choose a certain framework and foundation for sound. We notice, for instance, how instruments built in the 1970s and 80s are designed using a different ideology than certain instruments built today. This relates to how the frequencies in its tone are balanced (common adjectives used in this sense are often ‘rich,’ ‘feeble,’ ‘mellow’ or ‘rich on transients’), the thickness of the lid and the back of the instrument, the spacing between the lid and the strings, to name just a few of the differences.

The designs of various sorts of lutes are very much bound up with historical findings, as luthiers (i.e. lute builders) mostly seek to bring to life older authentic lutes rather than develop new instruments (one exception are the *Liuto Forte* lutes,<sup>2</sup> that have been appropriated to be more suitable for modern guitarists). However, experimentation with instruments has always been on the agenda. This is obvious since new instruments have always been developed, but we can also read written accounts on the matter. Mace (1676), for instance, writes about the invention of his two lutes in one instrument, the *dyphone*: “The *Occasion of Its Production*, was My

---

<sup>2</sup> See *Liuto Forte*. Retrieved 4 June 2017, URL: <http://www.liuto-forte.de>.

*Necessity; viz. My Great Defect in Hearing; adjoined with My Unsatiabable Love, and Desire after the Lute; It being an Instrument so Soft, and Past my Reach of Hearing, I did Imagine, it was possible to Contrive a Louder Lute, than ever any yet had been [...].*<sup>3</sup>

Historically, Wachsmann et al. informs us, the arched backside of the lute consists of an odd number of thin strips of wood<sup>4</sup> that are glued together and reinforced on the inside of the lute by strips of parchment or paper. When the size of the body increases, the number of ribs also increases (rather than simply widening the existing ribs). The ribs are normally held together by softwood (see subsequent section for explanation) at both ends, usually by a block at the top to interconnect with and support the neck. The soundboard is often constructed out of at least two thin, straight-grained plates (usually about 1.5 mm thick) of softwood, depending on the size of the instrument. From the 1590s on, ebony or some other type of hardwood was introduced along the border of the soundboard as a protective measure; however, as a trend developed of exchanging the more modern soundboard with an older one, the older solutions made a comeback to the instrumental design; only this time, the edges were wrapped in cloth or parchment.<sup>5</sup> The bridge was glued directly onto the soundboard and was usually crafted out of hardwood from pear, plum or walnut trees; strings were attached to it by pulling each string through a small, drilled hole and then looping it around itself, to secure it from losing its grip when the string is being tuned up to its proper pitch. To avoid distortion, due to the high tension of the strings, transverse bars are glued onto the underside of the soundboard, preferably from the same material. They function both to divide the soundboard into smaller, high-frequency resonant sections — favouring the harmonics of the string ( $f_1$  or higher) rather than the fundamental frequency ( $f_0$ ) — as well as adding support to the lid.<sup>6</sup> It is clear, then, from Wachsmann and his colleagues' description of historical

---

3 Mace, *Monument*, 203.

4 The type of wood used for the ribs does not seem to have been standardised and depended on what was available.

5 Wachsmann et al. suggests that the practice came into use 'possibly to cover pre-existing wear;' see Wachsmann, K., 'Lute,' in *Grove music online, Oxford music online*. Retrieved 18 July 2013, URL: [http://www.oxfordmusiconline.com/subscriber/article\\_citations/groove/music/40074pg3](http://www.oxfordmusiconline.com/subscriber/article_citations/groove/music/40074pg3).

6 Wachsmann, *Lute*.

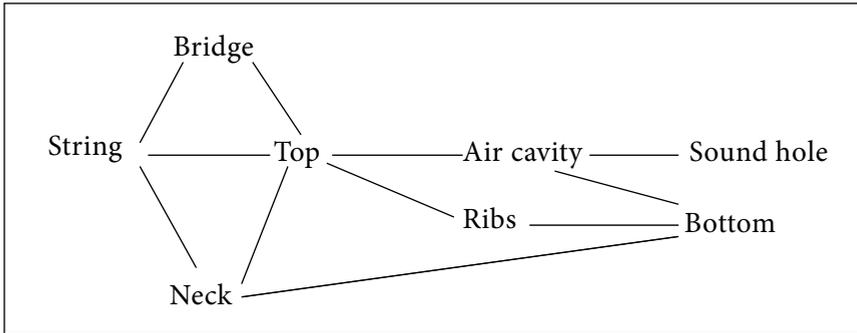
lutes, that it consists of many smaller parts, joined together into a whole. To understand how this constitutes lute sound, we must again turn our attention briefly towards some basic physics. Through the mathematical calculations accompanying the spring-mass system, we learn that all objects have a preferred frequency in which they oscillate depending on mass density and tension.<sup>7</sup> For instance, an anvil will have a higher frequency pitch upon beating it with a metal stick than would a smaller piece of wood, as the anvil has a higher mass density; tuning a lute string up heightens its pitch as the tension in the string increases. This was known already in the Early Modern period. Mersenne (1636), for one, said that the pitch produced by a string relates to the string's length, density, diameter and tension, and that length and diameter could compensate for the low density of gut strings;<sup>8</sup> consider the long bass strings of a theorbo and archlute (see Fig. 4.3). Also Mace (1676) writes that '[...] (indeed) *Length of String*, in any *Instrument*, causeth *Bravery*, and adds *Lustre to the Sound of That String*.<sup>9</sup>



**Figure 4.3.** My own theorbo with long bass strings, built by Lauri Niskanen. Photo: Robin Rolfhamre.

If we look at the individual parts of a lute we realise that it actually consists of multiple oscillators made of different materials, densities and tensions that create lute sound as they work together (see Fig. 4.4 below, bearing in mind that each part mentioned further consists of smaller pieces glued together). Lute sound then becomes a symphony of the mass

- 
- 7 Schnupp, J., Nelken, I., and King, A., *Auditory Neuroscience: Making Sense of Sound* (USA: MIT Press, 2011), 3–5.
- 8 Weinreich, G., et al., 'String,' *Grove Music Online, Oxford Music Online*, Oxford University Press. Retrieved 30 May. 2017, URL: <http://www.oxfordmusiconline.com/subscriber/article/grove/music/45984>.
- 9 Mace, *Monument*, 208.



**Figure 4.4.** The lute is constructed of multiple parts that function as oscillators.

density and tension of each part and their interaction as they are adjoined to one another — lute sound is the sum of its components and its construction. As we will see, the same equation (i.e. lute sound = part + part + part ... + part) can be followed throughout the production chain towards a live performance or the sound file played through your hi-fi system at home (see Chapter 6). Thus, choosing a certain luthier is also to choose a certain concept for sound production. Compare instruments built in the 1970s and the 1980s with more recently built instruments and you will find that they often differ a great deal with regard to construction, tone quality, loudness, distance between the lid and the strings, etc. So, choosing an instrument is also to choose a certain framework when developing our concept of ‘good’ lute sound and it sets the premises, not only for the sound coming out of the instrument, but also for how we relate to it both artistically and technically. It is, therefore, highly interesting and relevant to discuss wood as it makes up the vast majority of a lute, especially as it presents various perspectives that are both constant, subject to nature and subject to us as performers.

## Wood and the elements

Thomas Mace (1676) makes a great point of the synergy between instrument, strings and moisture. He emphasises the necessity for keeping moisture at an acceptable level to keep the instrument in shape, ease the handling of it while playing and, most interestingly, improve its tone production. Mace lays down seven good reasons for storing the lute properly:

And that you may know how to *shelter your Lute*, in the worst of *Ill wathers*, (which is *moist*) you shall do well, ever when you *Lay it by* in the day-time, to put *It into a Bed, that is constantly used, between the Rug and Blanket*; but *never* between the *Sheets*, because they may be *moist* with *Sweat*, &c.

This is the *most absolute and best place to keep It in always*, by which doing, you will find *many Great Conveniences*, which I shall here set down..[sic]

As, First, for the *saving* of your *Strings from Breaking*; for you shall not spend *half so many Strings* as another, who lays their *Lute* open in a *Damp Room*, or near a *Window*, &c.

2dly. It will keep your *Lute constantly in a Good Order*, so that you shall have but *small Trouble in the Tuning of It*.

3dly. You will find that it will *Sound more Lively and Briskly*, and give you *pleasure* in the very *Handling of It*.

4thly. If you have any *Occasion Extraordinary* to *set up your Lute* at a *Higher Pitch*, you may do *It safely*; which otherwise you cannot so well do, without *Danger* to your *Instrument* and *Strings*.

5thly. It will be a great *Safety to your Instrument*, in *keeping It from Decay*.

6thly. It will prevent *much Trouble*, as in *keeping the Barrs from flying Loose*, and the *Belly from sinking*.

Now these six considered all together, must needs create a *seventh*, which is, *That Lute-play must certainly be very much Facilitated*, and made *more Delightful Thereby*. [...]

I have now done with *Those Reasons*, why I would have a *Lute* kept most constantly in a *Bed*, when it is in *daily use*; But at other times, when it is *not used*, a *good warm Case, lined with Bayes within, and covered with Leather without, with Lock and Key, and Hasps*, will be very necessary.

Yet *All These* are *not a sufficient security* for *It*, if it should stand in a *Damp Room*, for then both *Lute and Case* will be all *mouldy*, and *Come in pieces*.

Therefore care must be taken that *It* always stand in some *warm Room*, where a *Fire is constantly used*, or (next to that) upon your *Bed-Testor*.

Let *This* suffice for keeping your *Lute safe*.<sup>10</sup>

---

10 Mace, *Monument*, 62 and 64.

Various sorts of wood are often categorised as *hardwoods* and *softwoods*. The difference between the two is not necessarily that one is hard and the other is soft, but that hardwoods comes from flowering plants (*angiosperm*), including oak maple and walnut, while softwoods comes from evergreen conifers (*gymnosperm*), including pine, spruce, cedar, yew and redwood. Softwoods tends (with some exceptions) to have a lower density and faster rate of growth than hardwoods. At a cellular level, hardwoods contain pores while softwoods do not which, logically, means that they are affected differently by humidity. Some instruments made with a lot of ebony (hardwood) in the neck,<sup>11</sup> or with ebony back ribs, seem to be more unstable when the climate changes than instruments with more softwood components. This is important in order to understand lute making in a historical context, because today we travel between different climates to a much greater extent than an Early Modern musician would have done. Indeed, it would not be unusual for a professional musician to find themselves in Kristiansand, Amsterdam and maybe even somewhere in Asia during the same week. This is in addition to the differences in temperature and humidity on the ground when the instrument is loaded on an aeroplane versus the very different climate and air pressure when flying at high altitudes. (This, of course, also affects non-wooden parts, such as the gut frets, which can seem drier and looser when arriving at the final destination than when the journey initially started.) *The Wood Database* clarifies the relation between wood and humidity from a *hygroscopic* perspective: ‘This means that wood, almost like a sponge, will gain or lose moisture from the air based upon the conditions of the surrounding environment.’<sup>12</sup> Additionally, it also expands and contracts according to the same conditions, which is often the reason for cracks and other problems related to wooden instruments. When temperature and humidity change, wood contracts and expands as it exchanges vapour with the

---

11 We can read in *The Burwell Lute Tutor*: ‘The flat part of the neck of the lute and the bridge are to be made of ebony; but to cover the head [and] the back of the neck with it as some do, ‘tis improper because it makes the lute too heavy upon the left hand, the neck cold and slippery for the thumb, and the frets are never fast’; see Dart, *Burwell*, 11.

12 The Wood Database, ‘Wood and Moisture’, *wood-database.com*. Retrieved 6 September 2017, URL: <http://www.wood-database.com/wood-articles/wood-and-moisture/>.

surrounding air, according to given principles. It does so according to the fibres and its original position in the tree from which it came.

Wood undergoes several stages of humidity during its journey from a tree to becoming part of an instrument. The first is when it is newly cut from the tree (called the ‘green state’), when it contains both bound water (trapped within the cells) and free water (liquid in pores and vessels). During exposure to air, it will immediately begin losing free water, without contracting or changing its dimensions given that the bound water is still intact. When all the free water has evaporated from the wood, it reaches its fibre saturation point (FSP), when it will begin to lose its bound water and reduce its volume; the green state now turns into a drying state. The bound water will, however, not be at a lower percentage than the surrounding humidity and temperature (i.e. relative humidity; RH). If the RH is 50%, the bound water of the wood will be 50%, where the percentage represents the weight of the water as compared to its oven-dry weight (i.e. 0% bound water). This point of stabilisation between RH and value below the FSP is called the ‘equilibrium moisture content’ (EMC), and it will change in accordance with the surrounding air temperature and RH. According to *The Wood Database* ‘Most interior buildings are kept between 30 to 60% RH, corresponding to 6 to 11% EMC. Exterior values can be much more variable depending on locale and season, but averages typically range from 30% to 80% RH, corresponding to 6 to 16% EMC.’ Keeping the room’s relative humidity in accordance to the instrument’s EMC prevents leaving the wood too dry (swelling the material during the humid summer) or leaving it too wet (leading to cracks and splitting in the dry winter). The same source adds ‘In this way, the wood is most likely to remain as close as possible to its intended size and shape.’<sup>13</sup>

What can be learned from *The Wood Database*’s remarks is not only that the relationship between RH and the instrument’s EMC is a matter of maintenance, keeping the instrument in shape, but also that the relation between the two affects the instrument’s tone production; stiffer, more contracted wood conducts sound propagation differently from slacker, more relaxed wood. Recall the spring-mass system mentioned earlier in

---

13 *The Wood Database, Wood and Moisture.*

this chapter; when tension and density changes, so too does the preferred pitch of the material and the resonance becomes altered as well.

If one is unfortunate, the climate can result in the wood bending as it shrinks, in relation to the original centre of the tree from which it came. According to Tim Padfield, this can be seen clearly in crackled, wooden antiques from China, where both wood and lacquer have dried out and shrunk over time, but at different rates, resulting in a crackled surface. This is because Chinese lacquer is applied at high relative humidity to speed up the hardening process, while in the present, it might be exposed to the modern, temperate indoor climate.<sup>14</sup> This is also why instruments sound different depending on the season and geographic location, and why we must account for these changes in our playing technique.

## Strings

Strings also react to the surroundings, of course, and choosing the right strings for an instrument is vital for how the instrument sounds; indeed, Descartes and others spoke of the strings as the ‘nervis testudinis’ (‘nerves of the lute’).<sup>15</sup> The modern performer can choose from a range of materials, including PVF carbon, nylon, nylgut, various sorts of gut, wound strings, metal strings, rectified, lacquered and other less common inventions. Choosing the right material has several practical purposes: 1) It helps to get the proportions right for the instrument to produce what we perceive as the right tone quality. Some instruments call for nylgut to unleash their full potential, while others call for PVF or some other material. Sometimes a combination is best; 2) It prevents the string from breaking when tuning the instrument to the desired pitch; 3) It prevents the bridge from jumping off the soundboard as a result of too much pressure from the strings together. We have already seen that pitch is related to density, tension and, as Mersenne pointed out earlier, also length. This is why different reference pitches call for different strings. Compare the

---

<sup>14</sup> Padfield, T., ‘The Reaction of Wood to Changing Climate,’ *Conservation Physics*. Retrieved 22 April 2016, URL: <http://www.conservationphysics.org/wood/wood1.php>.

<sup>15</sup> Descartes, R., *Musicae compendium*. Translated by T. Harper (Utrecht: Trajectum ad Rhenum, 1650), 12.

different dimensions of the strings on a Renaissance lute in G with a mensura of 60 cm tuned in 392 Hz, 415 Hz and 440 Hz respectively (see Table 4.1 below). The tension of each string is presented in N (Newtons) and not all the strings are presented. Here, we clearly see how the length of the string remains unchanged, but the dimension and tension alter to match the desired pitch. In Table 4.2 we also see how the dimension of the string changes when we alter the material of the string. This is a consequence of the differences between the materials' densities.

**Table 4.1.** Comparison between different reference pitches using gut strings.

| Pitch for 60 cm mensura (in this case, gut) | Reference a' = 392 Hz | a' = 415 Hz | a' = 440 Hz |
|---|-----------------------|-------------|-------------|
| g'; tension: 38 N                           | 0.46                  | 0.43        | 0.41        |
| d'; tension: 32 N                           | 0.56                  | 0.53        | 0.5         |
| a; tension 30 N                             | 0.73                  | 0.69        | 0.65        |
| f; tension 30 N                             | 0.9                   | 0.85        | 0.8         |

**Table 4.2.** Comparison between various types of strings over the same reference pitch.

| Pitch for 60 cm mensura (in this case, gut); a' = 440 Hz | Nylgut | PVF Carbon | Gut  | Nylon |
|--|--------|------------|------|-------|
| g'; tension: 38 N  | 42 NNG | 0.35       | 0.41 | 0.46  |
| d'; tension: 32 N  | 50 NNG | 0.42       | 0.5  | 0.57  |
| a; tension 30 N  | 66 NNG | 0.55       | 0.65 | 0.73  |
| f; tension 30 N  | 79 NNG | 0.68       | 0.8  | 0.91  |

## Historical sources

Historical strings are somewhat difficult to discuss in terms of tone production. The climate then and now is very different and the diet of animals has also changed, which again affects the quality of the guts. It is therefore not productive, from a performance perspective, to spend much time discussing earlier manufacturers across Europe (which was a relevant theme to discuss at the time, of course). I will rather direct attention to instructions regarding tone quality and ensuring the quality of strings.

There are several interesting remarks regarding strings to be found in the more practical sources. Vincenzo Capirola (c. 1517) describes how gut

strings are thicker at one end than the other and how it matters which way they are put on.<sup>16</sup> If they are put on the wrong way, they become false (i.e. out of tune). It is, therefore, important to get the two strings from the same length of gut so as to ensure that they are the same. If one is thicker than the other, it should be placed on top. Similarly, if one string of a course is bad, it doesn't matter how good the other is as the false string ruins the sound collectively:

Sapi che le corde sono fare de budeli de castroni: Et il cao del buclo sempre, e piu grosso che in fin: [...] Et replico come le se die ligar sul lauto, El contrabaso, et bordon, liga dal cao grosso, El tenor, mezane, sotane, vi ligade dal cao sottil [...] Nel bater la corda da veder, si sono bona, et iusta, per meter sul lauto, batila con la man destra per che anche nel sonare tu bari dal segno cun la man destra. Et fa che el cao longo, zoe el piu dela iavera stia nela man Zaneba, et la corda che son iusta bura do filli seguenti da un cao a laltro, et sapi, liga il cao piu iusto dal scagnello, Ancora sapi che si la[ ] corda te burase tre filli, o, g. Seguenti da[ ] un cao a laltro, faria ancora asai bona corda, Ma advertisi de acompagnar sempre la sua compagna de guela instesa bota zoe silabura .3. fili metili apreso unaltra da .3. fili, et cusi fa corda che non par false [...] Et si per sorte diro le mezane, o sotane no sacordase, et che fuse iuste, muda la corda da cao apie che forsi tacordara per la rason sopradita, per che ogni volte in le corde sotil non si puo cusi veder qual sia el cao piu grosso, o piu sotil da ligar sul scagnello, che per q[u]esta rason anche non fa[ ] corda. Et etian sapi a mudando la corda da cao a pie tacordara per [que-?] staltra causa che sara insta la corda dann cao che dal[ ] altro, ac etia sapi che nel ligar che fai la corda si lasasti inver il cagnelo in deo che corda falsa per sorte, non acordaria che te faria poi tuta la corda dalsa, cava mia la corda et rebatilla dare[ ] cao, et va provando, et facendo experientia [...] Et le mezane, et sotane, si per caso una fuse piu graseta del[ ] altra, meti sempre la grosa de sopra. Et etiam sapi che una corda falsa apreso de una insta mai tacordara, ma piu tosto de false aun [...] per che come il tasto, e piu propinguo a[ ] le corde, le corde adir cusi arpiza, et par mior el lauto [...].<sup>17</sup>

16 This is because the parts of the gut used for strings are naturally thicker at one end than the other; see: Larson, D., *Making Gut Strings*. Retrieved 12 June 2017, URL: <https://www.gamutmusic.com/new-page>.

17 Capirola, V., *Compositiōne*, ff. 3v–4r. For translation, see Marincola, *Capirola*.

(The strings are made from the gut of *castroni* [...] and the gut is always thicker on one hand than it is on the other [...] I shall repeat how to tie the strings on a lute: the 'contrabaso' and the 'bordon' from the thicker end, the 'tenor', 'mezane' and 'sotane' from the thinner end. [...] When you pluck a string, to check if it is good and right to put on the lute, pluck it with the right hand. As, when you play, you pluck it with the right hand from the (side of the) bridge. The longer end, or better, the rest of the hank of string should be held by the left hand. A good string makes two lines (which run) from one end to the other (of the string when plucked), and remember to tie the correct end of the string on the bridge. The string which makes three lines, which run from one end to the other (of the string) is still a very good one. Be always very careful to pair (the string) with another one of the same kind: if it makes three lines, pair it with another one which makes three lines; in this way (the two strings) will be in tune, and will not sound false. If, for instance, you cannot tune the 'sotane' or 'mezane', even if they are good, turn the end of the strings the other way around. For the already mentioned reasons you should then (be able to) tune them. In fact, with the thin strings, very often we cannot be sure which end is the thinner or the thicker one, to tie on the bridge, and for this reason we cannot tune it. If you turn the ends of a string the other way around, you will find that (the string) works better in one position than the other. // If, for instance, when you tie the string, you leave in front of the bridge one inch of false string you will not be able to tune it and the whole string is false. So, take off the string, pluck it again and try and check it. // If one of the 'mezane' or the 'sotane' is, by coincidence, thicker than the other, always put the thicker one uppermost. If you pair a false string with a good one, you will never be able to tune them, and you will just have two false strings. [...] In fact, the closer the fret is to the strings it makes the strings of the lute sound like those of the harp [I had to use this long sentence in order to translate the verb 'arpiza'] and the instrument sounds better.)

John Dowland's essay brings other perspectives to the agenda in Robert Dowland's *A Varietie of Lute-Lessons ...* (1610). He discusses how one may judge the physical quality of strings and how the performer must be well aware of this so as not to be cheated by the seller:

Ordinarily therefore wee choose *Lute-strings* by freshnesse, or new making: the which appeares unto us by their cleere and oylinesse, as they lye in the Boxe or

bundle; yet herein we are often deceived, for Oyle at any time will make strings looke cleere, and therefore this tricke is too too commonly used to them when they are old.

Now because Trebles are the principall strings wee neede to get, choose them of a faire and cleere whitish gray, or ash-color, and take one of the knots in your hand, but let it not be too small, for those give no sound, besides they will be either rotten for lacke of substance, or extreame false. Also open the bouts of one of the ends of the Knot, and then hold it up against the light, and looke that it be round and smooth: but if you discerne it to be curlie, as the thread of a curled Cypris, or horse hayre, (which you may as well feele as see) then refuse them, although they be both cleere and strong, because those strings were not well twisted, and therefore will never be true on the Instrument. For trying the strength of these strings, some doe set the top of their fore and middle finger on one of the ends of the Knot, which if they finde stiffe, they hould them then as good; but if it bend as wee say, through a dankish weakenesse, then they are not strong. Some againe doe take the end of the string between their teeth, and they plucke it, and thereby if it breake faseld at the end, then it is strong, but if it breake stubbed then it is weake. This Rule also is houlden for the breaking of a string betweene the hands. The best way, is to plucke out an end of the string (if the seller will siffer you, if hee will not affare your selfe that those strings which hee sheweth you are old or mingled,) and then looke for the cleernesse and faults before spoken, as also for faseling with little hayres. And againe looke amongst the bouts, at one end of the Knot, that the string be not parted, I meane one peece great and another small, then draw it hard betweene your hands, to try the strength, which done, hould it up againe against the light betweene your hands, and marke whether it be cleere as before; if it be not but looke muddie, as a browne thread, such strings are old, and have beene rubbed over with oyle to make them cleere. This choosing of strings is not alone for Trebles, but also for small and great Meanes: greater strings though they be ould are better to be borne withall, so the colour be good, but if they be fresh and new they will be cleere against the light, though their colour be blackish. [...]<sup>18</sup>

---

18 Dowland, J., 'Other Necessary Observations Belonging to the Lute,' in Robert Dowland, *Varietie of Lute-Lessons ...* (London, Thomas Adams, 1610): 12–18, 12.

*The Burwell Lute Tutor* (c.1670) informs us that the weather and climate are important for the quality of the string, and that the causes of bad, or false, strings include exposure to the elements, age and discolouration. We find concordance regarding the matter of the strings' clarity and that the two strings of each pair must be matched properly to have the instrument in tune. We are further enlightened that strings are best kept in oiled paper or in a hog's bladder to keep them from drying out, since gut is an organic material:

The good strings are made at Rome or about Rome and none that are good are made in any other place, except the great strings and octaves that are made at Lyons in France and nowhere else. They attribute that to the climate and to the waters. The strings are made of sheep's and cat's guts, and are twisted with a great deal of art. To be good they must be clear and transparent, smooth and well twisted, hard and strong; and new they are preserved in a white paper dipped in oil of almonds, or in a hog's bladder. They endure no moisture nor any excessive heat no more than the lute, but they will have a temperate air and place (but of the two the moisture is the worst). When they are open their goodness is known thus: holding the two ends in each hand and striking the string with the middle finger, if they part in two only; or if being laid upon the lute they do not jar. If the two strings can be made of one bunch they will agree the better; but it is hard to find two good strings of a length, therefore you must choose them as near as you can to the same bigness. The string must not be full of knots or gouty or rugged, nor be bigger in one place than in another. [...] You must then have always by you a pretty good store of good strings and be very exact in preserving them. You must put them to the lute with curiosity. Observe the bignesses of them and put no false ones; they become false several ways — if they be old, if they take air, if they be yellow, and (in one word) if they do not come from Rome.<sup>19</sup>

In *The Burwell Lute Tutor*, we also learn the reason (at least, according to this source) why Baroque lutes traditionally have, not only the first, but also the second course single-strung. Both the consistency of sound

---

<sup>19</sup> Dart, *Burwell*, 15–16.

during the performance of cadences and the tone quality of the second course itself are addressed:

The reason why we use but one second [[string]] is that the two seconds [[if combined to a single course]] will seldom agree, that the second of the two squeaking [doth] smother the other strings. Besides the cadence that is made upon the treble and the second is not so clear if there be two seconds.<sup>20</sup> (The [[ ]] signifies my own addition, not Dart's.)

Also agreeing with the main arguments presented here, Thomas Mace (1676) provides a lengthy discussion on where to find the best strings. His discussion of various sorts of strings stretches over several pages, but I am rather interested in a passage where he draws attention to the storage of strings, which concurs with *The Burwell Lute Tutor* with some additional details:

[...] they [i.e. the strings] may be very *Good* when you *buy them*, but *spoiled* in a *quarter of an hours time*, if they take *any wet*, or *moist Air*. Therefore your best way is, to *wrap them up close*, either in an *Oyl'd Paper*, a *Bladder*, or a *piece of Scar-cloath*, such as often comes over with *Them*, which you may (haply) *procure*, of them who sell your *Strings*: [...]

Which, when you have thus done, keep them in *some close Box*, or *Cupboard*; but not amongst *Linen*, (for that gives *moisture*;) and let them be in a *Room* where there is, or useth to be, a *Fire often*: And when at any time you *open them* for your *Use*, take heed, they lye not *too long open*, nor in a *dark Window*, or *moist place*: For *moisture* is the *worst Enemy* to your *Strings*.

Forget not, to *Tye*, or *bind them close*, or *hard together*.<sup>21</sup>

What we learn from the historical sources is that strings are not just strings. Choosing the right strings for the right occasion and maintaining them properly according to the selected material (an idea which applies to any material from any period of time), are crucial not only for a good tone, but also for keeping the strings in tune. Indeed, it is noticeable when playing with gut strings, at least in my experience, that after a while they

---

<sup>20</sup> Dart, *Burwell*, 17.

<sup>21</sup> Mace, *Monument*, 66–67.

become impossible to tune well. They may be fairly much in tune based on open strings but become ‘false’ in higher registers, and I have made similar observations using other materials as well, although not always equally as obvious. Today’s strings, nonetheless, are different from what was used then, for reasons already stated, so the natural progression of this argument must therefore lead us to modern practices, to see how they relate to the historical sources.

## A few notes on modern strings

Luthier Martin Shepherd (2017) describes how attempts at manufacturing historically-informed strings are still in their infancy. Nylon strings ruled the early years of the twentieth-century lute revival, utilising plain nylon for the trebles and silver wound with a nylon floss core for the basses. For obvious reasons, nylon produces quite a different sound than gut, which is probably the reason that those interested in lute instruments delved into gut-string manufacturing as more original sources were unveiled and made available. As many lutenists in the early stages of the revival were trained Classical guitarists, which is often the case today as well, it is worth noting that lute courses were often strung in unisons. This may have had to do with the lack of available historical sources at the time, as well as the octave stringing being an undiscovered, traditional novelty that may have sounded strange to many Classical guitarists.<sup>22</sup> Today, however, we seem to use gut strings as a starting point for what lute sound really is, and indeed it is an interesting process, reaching beyond synthetic factory production. Luthier and string manufacturer Daniel Larson (2017) describes the process of making gut strings, in which an animal is first slaughtered to provide the guts which are then sorted and prepared for manufacturing. Following this, the strings are processed and twisted before they are left to dry and ultimately polished. At this stage, the strings can be left as they are or they can be processed further into wound strings.<sup>23</sup>

---

22 Shepherd, M., *Lute Strings: Ancient and Modern*. Retrieved 12 June 2017, URL: <http://luteshop.co.uk/articles/stringing/>.

23 Larson, *Making*.

It seems that the wound strings receive the most attention from modern string manufacturers. Mimmo Peruffo (2008) points out a difficulty for modern string manufacturers, which is the transition from one string type to another (e.g. nylgut treble to silver wound in the basses, or any other combination) and as a result, the middle register is particularly difficult to solve. There are also difficulties related to octave courses where often a non-wound and a wound string are placed together to form one single course. Modern synthetic stringing has not yet been able to develop an appropriate string type for the mid-register; one possible approach to the issue, as Peruffo suggests, is to use aluminium wound strings and carbon strings to smooth the transition. He comments, ‘The string maker has very limited leeway indeed: putting together a good set of gut strings for the lute looks more like a tricky narrow path than a wide and easy highway.’<sup>24</sup> In this respect, it is interesting to note Peruffo’s employers, the string manufacturer Aquila’s list of the differences between old and new wound strings. They identify three sorts of wound strings used in the late seventeenth century to the nineteenth century, including:

- 1) *Close Wound*: the single wire spires are tightly wound touching one another. It is the still commonly used sort.
- 2) *Double Wound*: a second close wound layer is laid over the first one. Because of the large quantity of metal wound on the gut core they were employed on instruments with a short string length but requiring a low tuning, e.g. violoncello da spalla, 5th double bass string &c.
- 3) *Open wound* (demifilè): the single wire was wound so that the spires would not touch one another but with a space in-between equal or slightly wider than the wire diameter (see Françoise Le Cocq, Paris 1724); these strings were in use exclusively in the in 18th century as [a] transition between plain gut mid-register and close wound basses, e.g. Bass viol 4th, violin 3rd &c and D minor german [sic]

---

<sup>24</sup> Peruffo, M., *The Lute in its Historical Reality*. Retrieved 12 June 2017, URL: <http://ricerche.aquila-corde.com/wp-content/uploads/liuto-en.pdf>, 99.

baroque Lutes.<sup>25</sup> (Italic emphasis added; in the original, bold typeface was used)

These three types identify interesting developments, where the close wound seems to have been the general *modus operandi*, the double wound accommodated low register and short string length, and the open wound sought to address the middle-range problem from the eighteenth century on. The latter string type will not be treated specifically, since the scope of this book only stretches to the end of the seventeenth century, but it does acknowledge that the middle register was indeed a problem before that; otherwise it would not have been invented. Furthermore, there have to be differences between historical and modern strings, both because of the differing conditions in which the strings were and are made, and because modern string makers must use their own experience and expertise to fill in the gaps where historical evidence is scarce. According to Aquila (2017), in this case focusing on the highly-related violin strings, the historical wound strings present the following features:

- a) medium or high twist gut core.
- b) round metal wire winding.
- c) no silk ‘padding’ between core and metal winding.
- d) metal wire of silver, silvered copper, pure copper or its alloys (brass).
- e) different gut/wire ratio than the modern wound strings.

While the modern equivalents are characterised by:

- a) flat metal winding.
- b) stiff, low twist core.
- c) silk ‘padding’ between core and metal winding.
- d) employment of modern alloys like tungsten, nickel, &c.
- e) metal-biased gut/wire ratio.

---

25 Aquila Corde Armoniche, *Aquila Bow Wound Strings: Our Criterias*. Retrieved 12 June 2017, URL: <http://ricerche.aquilacorde.com/i-nostri-lavori/98/corde-rivestite-per-archi-i-nostri-criteri/>.

Hence the acoustical differences are quite noticeable and interest [*sic*] both dynamic and timbric aspects.<sup>26</sup>

This example demonstrates both that historical and modern strings seem to be different, but also that there is a need for them to be different. Given the conditions in which they are made, as well as the modern sense of what a good tone is, which is still highly related to much later musical practices, a simple remake would not be preferable today. This is further supported by the fact that we cannot know for sure all the necessary details from reading primary and secondary sources, nor the exact, original conditions of the very old, preserved strings which have been subject to the test of time.

Martin Shepherd also addresses the mid-range problem when he draws attention to the matter of dimension and elasticity. As strings become thicker the lower the pitch is, to preserve a suitable working tension, they also become less elastic and the sound becomes more and more short-lived and out of tune. He gives an example: ‘The sixth course of a lute is two octaves below the first course, and even when strung at a much lower tension still has to be about 3–4 times thicker. This increase in thickness as you go down into the bass creates a problem [...]’ One measure to address this issue is to put more twist in the string during production, but that only provides sufficient effect to a small degree, about which scholars, luthiers, performers and string makers disagree. Some have experimented (and continue to do so) with loading the gut strings with metallic salts to double the density of unloaded gut strings. Although certain historical paintings suggest the use of this method through the colour of the strings, it is less certain whether the literature concurs. Loaded strings would cause them to become, for instance, a reddish colour, while Mace et al. above emphasises that the strings should be clear. Yet, because the holes on the bridge through which the strings are attached are not bigger than they are on surviving instruments, the loaded gut string concept presents itself as a plausible theory. Otherwise, the strings would either be too big to fit the holes,

---

<sup>26</sup> Aquila, *Wound Strings*.

or the tension would be as low as half of what is accepted nowadays as common-sense practice. The pitch can, of course, be set higher in general, but then we will meet problems with the first course suddenly becoming too thin, and the differences in the bass-string diameter are still not large enough.<sup>27</sup> It is apparent that string making and string selection are complex matters. Indeed, they could have filled a full chapter on their own. They are part of a constant flux between historical conditions (as perceived by the interpreter), modern academic and practical expectations, professional and non-professional ideas of good sound, research combined with trial and error, and simple physics and deductive-constructive methodologies. This is further exemplified by surviving instruments and strings. The idea of choosing, preferring or designing modern ‘historical’ strings is thus not only about the strings themselves, but also about forming an idea of what function they should or could perform, and what is to be expected from them. Furthermore, it is difficult to compare the sonic quality between various types of strings. Trial and error by individual players is time consuming and expensive, and memory and preconceptions make it difficult to compare strings from memory which may have been tested several months apart. I would, here, very much have liked to be able to offer the reader enlightening charts comparing the sonic qualities (frequencies) and tone development over time (e.g. attack and decay) of the different types of strings available in all their various twists, loadings and varnishing. Such an investigation, however, would demand scientific-quality tools and laboratories which I do not at the time of writing have access to, and as such, I must postpone such ambitions for future research projects.

Moving on, beyond the level of understanding the strings themselves, we also find their internal relationship; that is, how they are matched and tuned together — their temperament.<sup>28</sup>

---

27 Shepherd, *Lute Strings*.

28 Further reading on the luthier-related topics presented so far in this chapter includes: Bachorik, J.E., *Lute Making: A Survey of Historical and Modern Construction* (USA: self-published, 1974); and Taylor, R.Z., *Make and Play the Lute* (Chichester: Argus Books Ltd., 1983).

## Temperaments, tension and sustain

Temperament, that is, how we tune instruments and intonate tones according to various principles and traditions, is a vast subject and any attempt to fully cover the topic in this context would seem somewhat unrealistic and unnecessary. Yet, temperament is crucial to tone production because it decides how multiple tones performed simultaneously and in relation to neighbouring tones and harmonies are both perceived and how their tone develops over time. In fact, much of an instrument's sustain, tension and richness of overtones are decided by its temperament.

Temperaments can be seen in two ways. The first is when playing monophonic music where we have more freedom in choosing temperament. Because we only consider the tonality horizontally, there are fewer consequences for the overall tonality. Local adjustments can be made within a set tuning by either moving the frets or changing the pitch by pulling or slacking the string with the finger. In polyphonic music, however, the selected temperament produces greater consequences because it has to function vertically over a period of time. This is one of the main reasons why the repertoire of certain instruments historically is often based on a few selected keys in close relation.

Set aside from historical points of arguments, traditions and various ideologies of aesthetics, the selected temperament relates directly to sustain and resonance. A good example here is Pythagorean tuning versus modern Western equal temperament. Western equal temperament divides every semitone into 100 cents, making it easy to calculate (1 semitone or 1 fret on a guitar =  $1 \times 100 = 100$ ; 5 semitones or 5 frets on a guitar =  $5 \times 100 = 500$ ). Pythagorean tuning, however, is strictly mathematical and based on the natural proportions of harmonics. If a string is represented by one whole, that is the full length of the string, we find the first harmonic ( $f_1$ ) at the half of it (Pythagorean ratio 2:1), the second ( $f_2$ ) by dividing the string into three parts (3:2), the third ( $f_3$ ) by dividing the string into four parts (4:3), etc. (see Table 4.3 below). They are reached by multiplying the fundamental frequency by whole numbers.

**Table 4.3.** Overview of a fundamental pitch and its first seven overtones.

| Order | Example pitch of a = 440 Hz | Multiplication | Relative interval from preceding tone |
|-------|-----------------------------|----------------|---------------------------------------|
| $f_0$ | 440 Hz                      | $f_0 \times 1$ | (unison)                              |
| $f_1$ | 880 Hz                      | $f_0 \times 2$ | octave                                |
| $f_2$ | 1320 Hz                     | $f_0 \times 3$ | fifth                                 |
| $f_3$ | 1760 Hz                     | $f_0 \times 4$ | fourth                                |
| $f_4$ | 2200 Hz                     | $f_0 \times 5$ | major third                           |
| $f_5$ | 2640 Hz                     | $f_0 \times 6$ | minor third                           |
| $f_6$ | 3080 Hz                     | $f_0 \times 7$ | subminor third                        |
| $f_7$ | 3520 Hz                     | $f_0 \times 8$ | supermajor second                     |

By choosing to play in Pythagorean tuning, we have the major benefit of an increased sustain, because the overtones of the string and the instrument align better, in theory, with the temperament. This is conditional upon the luthier properly matching the materials and components of the instrument (consider earlier discussion of the mass-spring system and lute sound as the sum of its components). In Table 4.4 below, we see how different Pythagorean temperament is from Western equal temperament. They both have the octave at 1200 cents, but otherwise they differ from 1.96 to an astonishing 11.73 cents.

**Table 4.4.** Comparison between Pythagorean and Western equal temperaments.

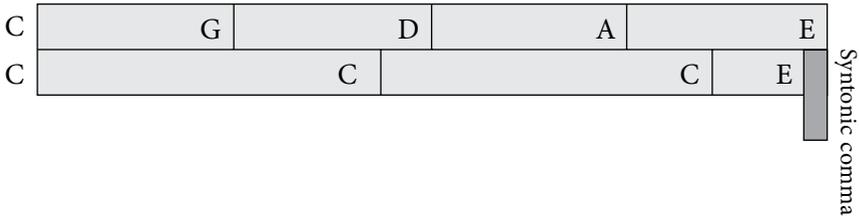
| Semitones | Pythagorean (in cents)                    | Western equal temperament (in cents) | Difference (in cents) |
|-----------|---|--------------------------------------|-----------------------|
| 1         | 90.22                                     | 100                                  | 9.78                  |
| 2         | 203.91                                    | 200                                  | 3.91                  |
| 3         | 294.13                                    | 300                                  | 5.87                  |
| 4         | 407.82                                    | 400                                  | 7.82                  |
| 5         | 498.04                                    | 500                                  | 1.96                  |
| 6         | Aug. fourth: 611.73<br>dim. Fifth: 588.27 | 600                                  | 11.73<br>11.73        |
| 7         | 701.96                                    | 700                                  | 1.96                  |
| 8         | 792.18                                    | 800                                  | 7.82                  |
| 9         | 905.87                                    | 900                                  | 5.87                  |
| 10        | 996.09                                    | 1000                                 | 3.91                  |
| 11        | 1109.78                                   | 1100                                 | 9.78                  |
| 12        | 1200                                      | 1200                                 | 0                     |

The crucial relationship here can be found between the fifth and the thirds. If we were to stack five pure fifths on top of each other from a reference note, such as 'C', we would reach an 'E'. Compared to similarly stacking two octaves and a pure third above each other, we would still go from 'C' to 'E', but the pitch would be different. At a time when the scientific measuring tools we have today were unavailable, this difference was used as a subjective measuring reference and we call it a *syntonic comma*. (See Fig. 4.5 below).<sup>29</sup> In the first system with the fifths stacked upon each other, we ensure that the fifths are pure according to Pythagorean principles, but the thirds are very much 'out of tune.' In the second system, however, where we stack two octaves and a pure third on top of each other, the thirds are pure, but the fifths are far too low. Put simply, these two principles mark the two core perspectives on temperament and tuning, even counterpoint, through the ages. In the Medieval period, harmony was not an issue and there was preference for pure unisons, fourths, fifths and octaves, which left the thirds to be considered as imperfect consonances and they were left out of important musical situations, such as the final chord of a musical work. This is understandable in a system promoting intervals based on natural harmonics, since the major thirds were indeed  $1/5$  of a semitone larger than the pure third, and the minor third was  $1/5$  of a semitone smaller than its pure relative. Not until the sixteenth century did the major third become an established part of the cadence (i.e. the *Picardy third*).<sup>30</sup> When the Renaissance period began, the fifths lost their favour to the pure thirds to better enable harmonies, but this came at the cost of leaving the fifths 'out of tune.' Various systems were created following this, in which the fifths were compromised at various degrees to accommodate harmonic progressions and modulations. The 'meantone system', or  $1/4$  comma system of tuning, lowered the fifths by  $1/4$  of the syntonic comma. This tuning sounds very nice on an instrument, but the harmonic restrictions are great indeed. As Rolf Lislevand pointed out to

---

29 Early Music Sources, 'Just Intonation,' YouTube video, 14'10", posted by 'Early Music Sources,' 6 October 2016, URL: [https://www.youtube.com/watch?v=XhY\\_7LT8eTw&feature=youtu.be](https://www.youtube.com/watch?v=XhY_7LT8eTw&feature=youtu.be).

30 Drabkin, W., 'Third,' *Grove Music Online*. *Oxford Music Online*, Oxford University Press. Retrieved 29 May 2017, URL: <http://www.oxfordmusiconline.com/subscriber/article/grove/music/27849>.



**Figure 4.5.** The syntonic comma. Adapted from *Early Music Sources* with permission.

me once during a private discussion, the fifth alone sounds awkward, but when the third is added it largely cancels out the fifth, making the harmony work much better. When the composers and musicians later asked for more distant harmonies, tuning had to be adjusted accordingly and a range of new temperaments arose, including  $1/5$  comma,  $1/6$  comma and  $2/7$  comma, etc. Indeed, the variations, or rather different compromises between fifths and thirds, are plentiful. In more recent years, Western equal temperament has tried to level out these differences (see Fig. 4.6 below) to enable musicians and composers to move freely between all possible keys, but the compromise is great indeed, and both fifths and thirds are out of tune according to natural harmonics. The positive effects of this are that they make a wider range of keys possible, and the composer and performer can explore distant keys within the same musical piece that are not closely related at all. The disadvantage of this, however, is that the intervals no longer align properly with the instrument’s and strings’ natural physics, making the tone duller with a shorter sustain.

|      |      |     |     |
|------|------|-----|-----|
| 700  | 700  | 700 | 700 |
| 1200 | 1200 | 400 |     |

**Figure 4.6.** The case of Figure 4.5 expressed in Western Equal Temperament. The intervals are expressed in cents.

What we can learn from this development, in order to understand tone production conceptually, is that tuning has no right or wrong configuration. It is dependent on personal preference, and historical and cultural contexts. Moving outside Western society, we find clear examples of more complex temperaments in the Far East, the Orient and Asia, and for anyone trying to learn Turkish music, for instance, one soon realises the

challenges of intonating when an octave is divided into 53 commas. A conceptual understanding of tuning and temperament is, then, also a matter of cultural understanding and ear training according to that specific culture. When further considering the matter of sustain and resonance, we understand that culture is also a part of the instrument's resonance and temperament. Instruments that seem to have been performed in more resonant acoustics seem to have had a stronger attack and shorter sustain, making them sound clear in large halls or their equivalent. Instruments that seem to have been utilised mostly in dry spaces, including several folk instruments such as the Norwegian Hardanger fiddle, the keyed fiddle and the hurdy gurdy, had the resonance built into the instrument by utilising sympathetic strings. Modern plucked instruments also have a much higher string tension and thicker materials which, together with shortened sustain and less apparent activation of unaligned overtones, makes them duller and often louder (depending on the performer) than their historically-distant counterparts.

## Practical considerations for lute instruments

Temperament, however, is not all that affects sustain, resonance and tone production. It is also important to include performance technique and instrument set-up when developing a concept for tone production. Regarding the left hand, the point at which one places one's fingers between two frets actually makes a difference. If the fingers are placed off centre, it can be difficult to press the string all the way down on the fretboard, which in turn affects the string's movement. This can result in shorter sustain and slightly-altered pitch, especially when the distance between the fretboard and the string is high (see Fig. 4.7 below). When placing the finger at the centre between two frets, it is easier to press the string down properly and reach full string tension (see Fig. 4.8 below). A good experiment to illustrate this, at least in my experience, is to play a D minor chord on a Baroque guitar, first with the fingers unevenly placed and then with all the fingers in the dead centre of each fret. What I notice is that the first case results in an unbalanced chord that sounds slightly out of tune, while the second case produces a well-balanced chord where all tones have similar sustain and are perceived as more in tune with each other. What is interesting to



**Figure 4.7.** Off centre: The strings have no contact with the fretboard, resulting in ineffective string vibrations and sometimes loss of sustain and altered pitch. Photo: Robin Rolffhamre.



**Figure 4.8.** At the centre: The strings have contact with the fretboard, resulting in effective string vibrations. Photo: Robin Rolffhamre.

note here is that I have found no primary sources, neither past nor present literature, which supports or even mentions this, except for Rolf Lislevand, who once raised the issue with me during a private conversation.

This is not necessarily true on all instruments. I have made observations that, in addition to modern Classical guitars and their relatives, the steel string instruments of old are less determined by the centre position. On my own *chitarra battente*, the difference between on and off centre is so minimal that I wonder if it is even perceptible. It is worth noting that John Playford (1666), in writing about the metal-strung cittern, says that '[...] To strive to stop clear; Which to do, be sure not to stop short of the Fret, not just upon it, but with the end of the finger as near the Fret as you can, and the harder the better.'<sup>31</sup>

Beyond the placing of the left-hand fingers, old frets cause various problems as well. First of all, they can become dry and loose, making them move around uncontrollably when the left hand moves up and down the fretboard. Secondly, when fibres break and the frets get rough and 'hairy,' the frets make unwanted contact with the vibrating string, causing noise as they disturb the trajectory of the string. Finally, unevenly-worn frets cause uneven heights, which in turn produce uneven tensions between strings, also affecting intonation and sustain; this means that a perfectly-tuned instrument, with all the frets correctly positioned, may still be out of tune because it has old frets (see Fig. 4.9 below). According to *The Burwell Lute Tutor*, 'The frets must be good and new, and tied very fast; [...] Now one cannot well tune his lute unless it be well strung and have good frets.'<sup>32</sup> Furthermore, Mace advises us to use single frets rather than some techniques of tying which result in double frets, as they produce a clearer tone. In Mace's words, double frets 'cannot be thought to *speak so Clear*, because, although it *Lye hard and close*, upon the *uppermost* of the *Two*, next the *Finger*, yet it cannot lye so very *close and hard*, upon the *undermost*; so that it must needs *Fuzz* a little, though not *easily discern'd*, and thereby, takes *off* something of *Its Clearness* [...].'<sup>33</sup>

---

31 Playford, *Cithren*, Brief Instructions to Playing the Cithren (7th page).

32 Dart, *Burwell*, 15–16.

33 Mace, *Monument*, 70.



**Figure 4.9.** The frets are so worn out that they affect the sound by being too low. Small fragments sticking out also disturb the string's vibration. Photo: Robin Rolfhamre.

## Performing in an acoustical space

Although there are several matters contributing to how a lute instrument performs physically, it has to be said that most of them take place during the construction of an instrument. Except for matters concerning humidity, geography and temperature, there is little one can do about the construction of a finished instrument other than make physical alterations to it, or to buy another instrument. It is indeed relevant to understand how the instrument behaves and why, in order to understand how sound develops in a certain context, but what is even more important for the practicing performer is to understand how it is affected by, and behaves, in an acoustical space. As mentioned earlier in this chapter, understanding a single particle's behaviour is simple enough, but when a multitude of particles are considered in relation to each other it all becomes highly complex.

A large portion of what shapes the sound of a lute in an acoustical space has to do with reflection. When sound impacts with a surface at a certain angle it will reflect at a corresponding angle. This means that if sound

approaches a wall from an angle of  $22^\circ$  from the left, it will project from the surface at an angle of  $22^\circ$  to the right. But not all sound is reflected. All materials absorb sound to various degrees, some more than others, which means that some sound is not reflected, but passes through the surface into the material. Painted concrete, for instance, absorbs around 10% at 125 Hz and 7% at 1000 Hz, while ordinary window glass absorbs around 35% at 125 Hz and 12% at 1000 Hz, leaving painted concrete as the most reflective material of the two.<sup>34</sup> But it is not as simple as that, because the absorption qualities of a material alter in relation to humidity as well. All materials have air pockets, to various degrees, depending on their density. When humidity increases, the surface's air pockets fill with water, making the material less absorbent and more reflective. Conversely, dryer spaces mean less reflection and reverberation.

*The Burwell Lute Tutor* reveals some traces of contemporary acoustics, 'You do well to play in a wainscot room where there is no furniture, if you can; let not the company exceed the number three or four, for the noise of a mouse is a hindrance to that music.'<sup>35</sup> In a later comment we also learn that:

the lute is a closet instrument that will suffer the company of but few hearers, and such as have a delicate ear; for the pearls are not to be cast before the swine. As I answered once to a gentlewoman that told me the lute was a heavy music: I answered that her ear was heavy, and that a violin was most fit for her [...] for the cabinet rather than for a public place.<sup>36</sup>

This was quite a rude remark, comparing the noblewoman to 'the swine'; particularly when considering Leppert's argument that the violin was a popular instrument for the lower classes in the seventeenth century, 'who used it principally to accompany dances.'<sup>37</sup> Indeed, in *The Burwell Lute Tutor* we read: 'To make people dance with the lute it is improper.'<sup>38</sup>

---

34 Everest, F.A., and Pohlmann, K.C., *Master Handbook of Acoustics*, fifth edition (USA: McGraw Hill, 2009), 481.

35 Dart, *Burwell*, 45.

36 Dart, *Burwell*, 60–61.

37 Leppert, *The Sight*, 34.

38 Dart, *Burwell*, 62.

Thomas Mace (1676) also speaks of acoustics and presents a sketch of a ‘*Most Excellent Musick Room*’ which he comments accordingly:

The *1st Thing* to be consider’d, as to the *Advantage of Good Musick*, should be a Convenient, and Fit *Place* to perform It in; such I would call a *Musick Room*; and is considerable in a *4 Fold Respect*, *1st.* in *Respect* of, the *Instruments*, *2d.* the *Musick*, *3d.* the *Actors*, and *4th* the *Auditors*. [...]

Again; tis observable, That all *Persons* who pursue *Musick*, do endeavour to procure the *Best Instruments* that can be gotten. Now let the *Instruments* be what they will, a *Good Room* will make Them seem *Better*, and a *Bad Room*, *Worse*, as I said before: Therefore It is of a *Great Concern*, to have a *Room*, which may at least, *Advantage your Instruments*, if no other *Conveniency* were gain’d thereby. [...]

Here, Mace touches upon one of the core arguments of this book as he speaks of a *music* room that functions as a relation between the instrument, music, performer and perceiver (in this case, the audience). He continues to emphasise that the quality of sound demands both a good, level instrument and good acoustics, and that they are properly contextualised by the performer to have the room emphasise the best qualities of the instrument; that is, the performer must take the acoustics into consideration to achieve the best tone quality. Mace continues to present, what he perceives to be, the most-suitable music room:

The *Room* would be *One Step Higher*, than the *Galleries*, in the *Floor*; the better to conveigh the *Sound* to the *Auditors*.

The *Height* of the *Room* not too *High*, for the same *Reason*.

[...]

The *Room* being *Thus Clear*, and *Free from Company*, all *Inconveniencies* of *Talking*, *Crowding*, *Sweating*, and *Blustering*, &c. are taken away.

*2d.* The *Sound* has Its *Free*, and *Un-interrupted Passage*, &c.

*3d.* The *Performers* are no ways *Hindered*, &c.

*4th.* The *Instruments* will stand more steadily in *Tune* [...].

*5thly*, The *Musick* will be *Equal* to all alike.<sup>39</sup>

---

39 Mace, *Monument*, 238–240.

Note how Mace presents perspectives similar to those of Rogers, such as having a small audience and giving sound an uninterrupted, free passage. Mace goes further, however, commenting on how the acoustical space affects tuning and that a proper space for music does not differentiate the tone qualities among the auditors; it is perceived alike by all. Mace's argument here is somewhat different than mine in the sense that Mace speaks of constructing a space for music, while I am concerned with tone production in an already-existing space, be it perceived as good or bad. But what we can draw from his discussion is the aim of controlling tone quality and musical expression, to the extent that the musicians are not hindered, neither by instruments and acoustics, nor audiences, in their mediation. Mace's passage on acoustics is quite extensive compared to other topics discussed in *Musick's Monument*, and he proceeds to describe more and more intricate solutions to the interior design, such as 'by Groves, or Pipes, to certain Auditors Seats, where (as they sit) they may, at *small Passage*, or *little Hole*, receive that *Pent-up-Sound*'.<sup>40</sup> Rogers and Mace are, of course, only two sources (both from England) and they do not alone represent the full perspective of the ideology of acoustics in Early Modern times. What they do is to give us an important indicator of the Early Modern musician's consciousness of acoustics as an important part of music performance. Continuing along Mace's line of argument, focusing on the sentence 'The *Musick* will be *Equal* to all alike,' we cannot proceed without addressing the issue of phase and comb filtering, because this has a great deal to do with how we perceive a tone. If sound is propagated hemispherically, it means that sound will impact with different surfaces at different times, reaching the ears of the listener at various temporal locations. This is also what makes an instrument sound different in diverse acoustical spaces, because sound as a design is perceived in relation to the space in which it is being created. Phase and comb filtering are important matters in this regard, as they explain why this is happening. The speed of sound is often said to be around 344 metres per second, but in reality, it depends on the temperature, following the formula  $331.4 + (0.607 * T)$  where T is

---

<sup>40</sup> Mace, *Monument*, 240.

temperature in Celsius.<sup>41</sup> If the temperature is 22°C, sound travels at a speed of 344.6 metres per second, but if the temperature is 5°C, its speed is reduced to 334.4 metres per second. If we have two identical sounds played at the same time, the amplitude (i.e. the force at which the particles are displaced) is doubled; if we invert the phase of one of the identical sounds (i.e. turn it up-side-down), we hear nothing because the positive amplitude of one sound is cancelled out by the equally-large negative amplitude making the matter particles stand still, *ergo*, no sound (if two people pull an object in opposite directions with equal force, the object will not move, as the forces cancel each other out); however, if the one sound is slightly displaced relative to the other, some frequencies are amplified and some are cancelled out (on a spectrogram this would look like a comb). This is called comb filtering and this is what makes a certain tone sound the way it does.

As sound is propagating and reflecting inside a room, some sound is obliged to fit the room's dimension in such a manner and angle that it bounces back and forth between two fixed points. This causes some frequencies to become amplified and some to be attenuated or even cancelled, according to the principles of phase and comb filtering mentioned above. Such behaviour gives rise to a phenomenon called *room modes*. All rooms have preferred frequencies, that is, tones that are reinforced by the room and perceived as stronger sounding than other tones. This also happens inside instruments, which we may consider as very small rooms. I recently had the good fortune to perform two Italian, traditional tarantellas with a talented violinist in Sweden; the first was in G major and the second in A minor. What we observed was that the violin reacted very differently to the two keys, and the violinist told me that in the A minor tarantella, the instrument produced the tone by itself in a sense, while in the G major tarantella, she had to 'do all the work' herself. This is a typical and clear example of how the room modes unveil themselves through an instrument.

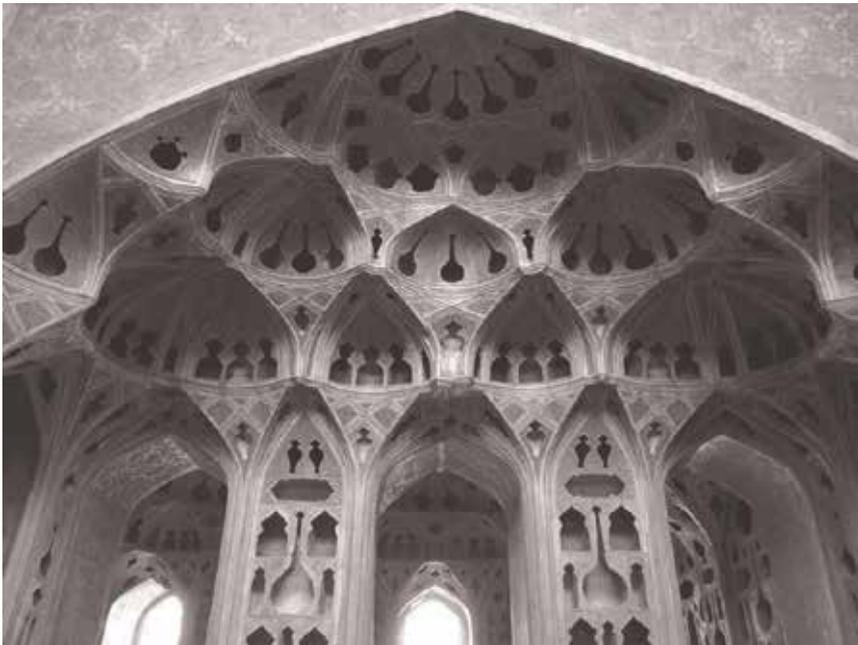
Room modes are not only an indicator of what sounds subjectively good or bad in a room, or what frequencies are strengthened or weakened,

---

41 Rayburn, R.A., *Eargle's Microphone Book: From Mono to Stereo to Surround. A Guide to Microphone Design and Application*, 3rd ed. (USA: Focal Press, 2013), 11.

but they can also be used in reverse engineering. In an interesting study by Hassan Azad, attempts are made to recreate historical acoustics to learn more about how music could have sounded. Azad studies the music room of the Safavid palace, Ali Qapu in Isfahan, Iran, and finds that it has quite intimate acoustics despite its large construction (see Fig. 4.10 below). From this we learn that large spaces and intimate acoustics are not necessarily opposites:

The reverberation time was nearly low in all configurations. This means that Ali Qapu has been so suitable for intimate music especially Iranian ballad which is a part of Iranian traditional music performed in that era. [...] In spite of high proportion of the room volume to the audience between 8 to  $10^3$  per person, the presence of cut-outs brought about low reverberation time to serve the function of the room as a host for speech and intimate music.<sup>42</sup>



**Figure 4.10.** Music Room. The acoustic ceiling of the rooftop music room of the Ali Qapu Palace in Isfahan, Iran. Photo: David Stanley. Published on Flickr under a Creative Commons Attribution 2.0 Generic license (CC BY 2.0); some rights reserved. Original photograph in colour.

42 Azad, H., 'Ali Qapu: Persian Historical Music Room.' *Proceedings of the Institute of Acoustics*, 30 (2008) Pt.3., 4.

In this chapter, we have moved from the instrument-centric to the external and we have now reached a point where the musical instrument takes part in an acoustical environment. Tone production, both seen as a physical, theoretical phenomenon and as a concept, has now become part of an external space and so we must also consider how we as performers and audience members relate to tone production from psychological perspectives. The following chapter will introduce some key perspectives, mainly from social psychology, from which we can contextualise the historical texts (Chapter 2), the modern interpreter instructions (Chapter 3) and the physics of tone production (Chapter 4), to reach a better understanding of how we subjectively and socially form our own concept of proper tone production.

