

# What is Rhythm?

**R**HYTHM IS A FUNDAMENTAL FEATURE of all aspects of life.<sup>1</sup> Creating music, listening to music, and dancing to the rhythms of music are practices cherished in cultures all over the world. Although the function of music as a survival strategy in the evolution of human species is a hotly debated topic, there is little doubt that music satisfies a deep human need.<sup>2</sup> To the ancient philosopher Confucius, good music symbolized the harmony between heaven and earth.<sup>3</sup> The nineteenth-century philosopher Friedrich Nietzsche puts it this way: "without music life would be a mistake."<sup>4</sup> And the Blackfoot people roaming the North American prairies "traditionally believed that they could not live without their songs."<sup>5</sup>

Of the many components that make up music, two stand tall above all others: rhythm and melody. Rhythm is associated with time and the horizontal direction in a typical Western music score. Melody, on the other hand, is associated with pitch and the vertical direction. Rhythm can do very well without melody, but melody cannot exist without rhythm. Although rhythm and melody may be studied independently, in music, they generally interact together and influence each other in complex ways.<sup>6</sup> Experimental results have shown that melody and rhythm (pitch and time) can be encoded in the human brain, either independently or in a combined manner, which depends on the structure of the melody as well as the experience of the listener.<sup>7</sup> Of these two properties, rhythm is considered by many scholars to be the most fundamental of the two, and it has been argued that the development of rhythm predates that of melody in evolutionary terms.<sup>8</sup> "Rhythm is music's central organizing structure."<sup>9</sup> The ancient Greeks maintained that without rhythm, melody lacked strength and form. Martin L.

West writes: "rhythm is the vital soul of music,"<sup>10</sup> the philosopher Andy Hamilton notes that "rhythm is the one indispensable element of all music,"<sup>11</sup> and Ton de Leeuw considers that "rhythm is the highest and most autonomous expression of time-consciousness."<sup>12</sup> Joseph Schillinger writes: "The temporal flow of music is primarily a matter of rhythm."<sup>13</sup> Christopher Hasty offers a concise universal definition of music as the "rhythmization of sound."<sup>14</sup> From the scientific perspective, psychological experiments designed to assess the dimensional features of the music space, based on similarity judgments of pairs of melodic fragments, suggest that the major dimensions are rhythmic rather than melodic.<sup>15</sup> The American composer George Gershwin believed that the public loved his music because of its rhythm, and in analyzing his rhythms, Isabel Morse Jones writes: "Gershwin has found definite laws of rhythm as mathematical and precise as any science."<sup>16</sup>

Curt Sachs asks the question: "What is rhythm?" and replies: "The answer, I am afraid is, so far just—a word: a word without a generally accepted meaning. Everybody believes himself entitled to usurp it for an arbitrary definition of his own. The confusion is terrifying indeed."<sup>17</sup> In other words, there is no simple answer to this question. Christopher Hasty cautions that "rhythm is often regarded as one of the most problematic and least understood aspects of music."<sup>18</sup> James Beament echoes this sentiment when he writes: "Rhythm is often considered the most difficult feature of music to understand."<sup>19</sup> For Robert Kauffman "The difficulties of dealing with rhythm are immense."<sup>20</sup> Wallace Berry writes: "The awesome complexity of problems of rhythmic structure and analysis can be seen when one appreciates that rhythm is a generic factor."<sup>21</sup> Berry goes on to note that

another consideration that makes studying rhythm difficult is the fact that meanings ascribed to terms such as "rhythm," "meter," "accent," "duration," and "syncope" are vague and used inconsistently. Elsewhere he writes more concisely: "Rhythm is: everything."<sup>22</sup> In spite of some of these difficulties, or perhaps because of them, many definitions of rhythm have been offered throughout the centuries. Already in 1973, Kolinski wrote that more than 50 definitions of rhythm could be found in the music literature.<sup>23</sup> Before diving into the geometric intricacies of rhythm that are explored in this book, it is instructive to review a few examples of definitions and characterizations of rhythm, both ancient and modern.

*Plato*: "An order of movement."<sup>24</sup>

*Baccheios the Elder*: "A measuring of time by means of some kind of movement."<sup>25</sup>

*Phaedrus*: "Some measured thesis of syllables, placed together in certain ways."<sup>26</sup>

*Aristoxenus*: "Time, divided by any of those things that are capable of being rhythmized."<sup>27</sup>

*Nichomachus*: "Well marked movement of 'times'."<sup>28</sup>

*Leophrantus*: "Putting together of 'times' in due proportion, considered with regard to symmetry amongst them."<sup>29</sup>

*Didymus*: "A schematic arrangement of sounds."<sup>30</sup>

*Aristides Quintilianus*: "Rhythm is a scale of chronoi compounded according to some order, and the conditions of these we call arsis and thesis, noise and quietude."<sup>31</sup>

*Vincent d'Indy*: "Rhythm is the primordial element. One must consider it as anterior to all other elements of music."<sup>32</sup>

*S. Hollos and J. R. Hollos*: "In its most general form rhythm is simply a recurring sequence of events."<sup>33</sup>

*S. K. Langer*: Rhythm is "The setting-up of new tensions by the resolution of former ones."<sup>34</sup>

*H. W. Percival*: "The character and meaning of thought expressed through the measure or movement in sound or form, or by written signs or words."<sup>35</sup>

*D. Wright*: "Rhythm is the way in which time is organized within measures."<sup>36</sup>

*A. C. Lewis*: "Rhythm is the language of time."<sup>37</sup>

*J. Martineau*: "Rhythm is the component of music that punctuates time, carrying us from one beat

to the next, and it subdivides into simple ratios."<sup>38</sup>

*A. C. Hall*: "Rhythm is made by durations of sound and silence and by accent."<sup>39</sup>

*T. H. Garland and C. V. Kahn*: "Rhythm is created whenever the time continuum is split up into pieces by some sound or movement."<sup>40</sup>

*J. Bamberger*: "The many different ways in which time is organized in music."<sup>41</sup>

*J. Clough, J. Conley, and C. Boge*: "Patterns of duration and accent of musical sounds moving through time."<sup>42</sup>

*G. Cooper and L. B. Meyer*: "Rhythm may be defined as the way in which one or more unaccented beats are grouped in relation to an accented one."<sup>43</sup>

*D. J. Levitin*: "Rhythm refers to the durations of a series of notes, and to the way that they group together into units."<sup>44</sup>

*P. Vuust and M. A. G. Witek*: "Rhythm is a pattern of discrete durations and is largely thought to depend on the underlying perceptual mechanisms of grouping."<sup>45</sup>

*A. D. Patel*: "The systematic patterning of sound in terms of timing, accent, and grouping."<sup>46</sup>

*R. Parncutt*: "A musical rhythm is an acoustic sequence evoking a sensation of pulse."<sup>47</sup>

*C. B. Monahan, and E. C. Carterette*: "Rhythm is the perception of both regular and irregular accent patterns and their interaction."<sup>48</sup>

*M. Clayton*: "Rhythm, then, may be interpreted either as an alternation of stresses or as a succession of durations."<sup>49</sup>

*B. C. Wade*: "A rhythm is a specific succession of durations."<sup>50</sup>

*J. London*: "A sequential pattern of durations, relatively independent of metre or phrase structure."<sup>51</sup>

*S. Chashchina*: "Rhythm is a sequence of durations of sounds, disregarding their pitch."<sup>52</sup>

*A. J. Milne, and R. T. Dean*: "A sequence of sonic events arranged in time, and thus primarily characterized by their inter-onset intervals."<sup>53</sup>

*S. Arom*: "For there to be rhythm, sequences of audible events must be characterized by contrasting features."<sup>54</sup> Arom goes on to specify that there are three types of contrasting features that may operate in combination: *duration*, *accent*, and *tone colour (timbre)*. Contrast in

each of these may be present or absent, and when accentuation or tone contrasts are present they may be regular or irregular. With these marking parameters Arom generates a combinatorial classification of rhythms.<sup>55</sup>

C. Egerton Lowe writes: "There is, I think, no other term used in music over which more ambiguity is shown." Then he provides a discussion of a dozen definitions found in the literature.<sup>56</sup>

The reader must have surely noticed that the various definitions enumerated earlier emphasize different properties of the term rhythm. Perhaps, the most distinct of these definitions (and certainly the shortest) is the earliest one by Plato, in terms of movement, which we can interpret as dance. W. T. Fitch and Rosenfeld, A. J. (2016) argue that the important aspects of musical rhythm "cannot be properly understood without reference to movement and dance, and that the persistent tendency of 'art music' to divorce itself from motion and dance is a regrettable phenomenon to be resisted by both audiences and theorists."<sup>57</sup>

Some of these definitions imply that a rhythm must be "good" to qualify as being a rhythm. Leophantus, for example, insists that the durations that make up a rhythm must exhibit due *proportions* and *symmetry*. While the question of what makes a "good" rhythm good is a central concern in this book, the definition adopted here is neutral on this issue. A more relevant property of the definitions listed earlier discriminates between rhythms that are either general or specific. Perhaps the most general definition is that of Hollos and Hollos as "a recurring sequence of events." Here it is not specified if the events are visual, aural, or time dependent. Most definitions do involve the notion of time. The *Harvard Dictionary of Music* distinguishes explicitly between general and specific rhythms. Its general definition of rhythm echoes that of Plato with the notion of time thrown in: "The pattern of movement in time." Its specific definition of "a rhythm" is: "A patterned configuration of attacks."<sup>58</sup> When we listen to a piece of music such as "Hey, Bo Diddley," we hear several instruments, each playing a different rhythm. Some instruments are playing solos with rhythmic patterns that vary, while other instruments repeat rhythms throughout. The singer adds yet another layer of rhythm. What is the rhythm of such a piece? The answer to this question corresponds to the *general* definition of rhythm given by the *Harvard*

*Dictionary of Music*, and is exceedingly difficult to ascertain. This book is not concerned with either the objective rhythmic signal, or its subjective perception, that result when a *group* of rhythms is played and heard simultaneously, but rather with the *specific* definition of a rhythm given by the *Harvard Dictionary of Music*: a "patterned configuration of attacks." Furthermore, the emphasis is on rhythm considered as a sequence of durations, disregarding not only meter and pitch, but everything else as well. In addition, the focus is on a particular class of distinguished rhythms: those that are repeated throughout most or all of a piece of music.

Apart from the many conceptual definitions of rhythm listed earlier, we all know experientially what rhythm is, because it is a natural phenomenon, an inherent aspect of nature. Even before we come into this world, while we are still in the womb, we are already bathed in the steady comforting rhythm of our mother's thumping heartbeat and her smooth breathing.<sup>59</sup> Figure 1.1 (top) shows a greatly simplified schematic diagram of the waveform that shows up in an electrocardiogram of a beating heart. The horizontal axis measures time, and the evenly spaced spikes indicate instants of time at which a healthy heartbeat is heard. Since we are only interested in the points in time at which the spikes occur (and not their height), the waveform may be represented as a string of elements (Figure 1.1—middle) in which a mark is made wherever a spike occurs. However, the white rectangles representing the spaces between the spikes are now longer than the black squares representing the spikes. It is most convenient for the analysis of rhythmic patterns to divide these long interspike intervals (silences) into smaller silent units that have the same duration as the sounded units (Figure 1.1—bottom). In this way, the heartbeat has been reduced to a *pulsation*, a binary string (sequence) of evenly spaced pulses, some of which are sounded (attacks) while others remain silent (rests). The term pulse is used in this book to denote the location at which a sound or attack may be realized. This representation of rhythm is also called box notation.<sup>60</sup> A convenient way to write box-notation in running text is to use the symbol [x] for a black square (attack) and the period symbol [.] for a white square (rest). Thus, the rhythm at the bottom of Figure 1.1 may be written in box notation as [x . . . x . . . x . . . x . . . x . . .].

It is often said that rhythm is in the mind and not in the acoustic signal. Grosvenor Cooper and Leonard B. Meyer write: "Rhythmic grouping is a mental fact, not



FIGURE 1.1 The idealized heartbeat represented as a sequence of binary elements.

a physical one.”<sup>61</sup> This statement should of course not be taken literally. Besides the fact that at present we still do not know that the mind is not physical, and that there exist machines such as functional magnetic resonance imaging and magnetoencephalography that record physical manifestations of rhythm in the brain, the fact is that whether or not grouping is physical, what we perceive as rhythm emanates from an acoustic physical signal. Although William Sethares is right to point out that “many of the most important rhythmic structures are present only in the mind’s ear,”<sup>62</sup> the converse is also true: many of the most important rhythmic structures are present only in the physical signal or the symbolic score. Indeed, music psychologists have found compelling evidence that everyone, whether trained musicians or not, can discriminate among the styles of western classical music based solely on the variability of the durations of the notes, as measured by their standard deviation and normalized pairwise variability index.<sup>63</sup> Therefore, it is more accurate to characterize rhythm as a manifestation of a *process* that emerges from the amalgamation of a physical signal with perceptual and cognitive structures of the mind. Such a broad definition naturally leaves open the door to consideration, for analysis, any of the multitude of complex features that make up rhythmic patterns. As such, rhythm may be studied at any level in between these two extremes, ranging from the purely objective mathematical and scientific<sup>64</sup> approaches to the experiential “mythopoetic explanations”<sup>65</sup> as well as its spiritual roots.<sup>66</sup> Knowledge gained from such studies helps us to understand the totality of rhythm.

In this book, musical rhythm is studied predominantly at one extreme of the earlier panorama: rhythm

is considered purely in durational terms as a symbolic binary sequence of isochronous elements representing sounds and silences. Simha Arom writes: “In the absence of accentuation or differences in tone color, contrasting durations are the only criterion for the determination of rhythm.”<sup>67</sup> This is the simplest definition of rhythm possible. Since rhythm is considered to be such a difficult topic, it behooves us to understand it at this level well, especially when exploring and evaluating new tools, before moving on to higher ground. We should first understand precisely what we lose by confining ourselves to such a skeletal definition of rhythm as well as how much we can gain from it. In this book, I attempt to demonstrate what we can gain by combining geometric methods with such a simple and unambiguous objective definition of rhythm. Some researchers have argued that rhythm must be studied in a cultural and social context.<sup>68</sup> This is a perfectly valid endeavor, particularly so if the main interest is sociology or anthropology, just as it is of interest to study Einstein’s theory of general relativity or his equation  $E = mc^2$ , to gain insight into the structure of scientific revolutions, in a sociocultural context. However, the physical laws of the universe are independent of culture, although their description may be culturally determined, and arguably so are the physical laws of rhythmic patterns. John McLaughlin puts it this way: “The mathematics of rhythm is universal. They don’t belong to any particular culture.”<sup>69</sup> Here we take the position of Kofi Agawu with respect to the application of analytic methods to ethnomusicology, which may be extended to musicology in general: “Given the relative paucity of analyses, erecting barriers against one or another approach seems premature.”<sup>70</sup> Furthermore,

although thinking about musical rhythm in a mathematical way, using mathematical terminology,<sup>71</sup> may be quite inharmonious with certain cultural traditions,<sup>72</sup> it facilitates another goal of this book, the exploration of geometric rhythmic universals.<sup>73</sup> However, it should be emphasized that employing mathematical terminology in no way implies gratuitous use of the language of numbers and abstruse symbols. Rigorous mathematical discourse is possible with simple and clear English language, and this is the method favored in this book, to make the concepts within reach of a wide audience.<sup>74</sup>

Just as music is made up of many components, rhythm being one of them, so is rhythm. Three of rhythm's principal elements are meter, beat, and tempo.<sup>75</sup> It is possible that, in the past, rhythm has been difficult to dissect, because not enough attention has been given to its components and their interaction, or its myriad definitions have been too vague, or too general, or because it has not received enough attention from a purely objective mathematical point of view. To quote Curt Sachs's, "Rhythm weakens the more we widen its concept and scope."<sup>76</sup> It is hoped that the analysis presented in this book, of "rhythms" as ideal, narrow, purely mathematical, culturally independent, and binary symbolic sequences, will stimulate future progress in the systematic and comparative study of rhythm's subconstituent elements, and rhythm as a whole, in the context of perception, cognition, culture, and *world music theory*.<sup>77</sup> This is not to suggest that the psychological and cultural aspects of rhythm should be ignored in future research on rhythm. Indeed, "for a true understanding, the power of mathematics should be applied to the process of musical behavior, not merely to its product."<sup>78</sup> The stance taken here is that such a humanistic endeavor is best left to the behavioral psychologists. In this book, on the other hand, the main focus is on the mathematical properties of the *product* and the mathematical models of the *processes* that generate it.

## NOTES

- 1 Glass, L. & Mackey, M. C., (1988).
- 2 Huron, D., (2009), Bispham, J., (2006), and Cross, I., (1999, 2001).
- 3 Lau, F., (2008), p. 119.
- 4 Nietzsche, F., (1889). This quotation comes from the 33rd Maxims and Arrows in the book *Die Götzen-Dämmerung* (*Twilight of the Gods*).
- 5 Nettle, B., (2005), p. 23.
- 6 Monahan, C. B. & Carterette, E. C., (1985). However, in many parts of the world, such as India, Iran, and the Arab world "musical rhythm is a highly artistic element, self-contained in its rich and most intricate composition, and conceived quite independently of the melodic line." See Gerson-Kiwi, E., (1952), p. 18.
- 7 Boltz, M. G., (1999), p. 67.
- 8 Benzon, W. L., (1993).
- 9 Thaut, M. H., Trimarchi, P. D., & Parsons, L. M., (2014), p. 429.
- 10 West, M. L., (1992), p. 129.
- 11 Hamilton, A., (2007), p. 122.
- 12 De Leew, T., (2005), p. 38.
- 13 Schillinger, J., (2004), p. vi.
- 14 Hasty, C. F., (1997), p. 3. See Gow, G. C., (1915) for arguments that rhythm is the life of music.
- 15 Monahan, C. B. & Carterette, E. C., (1985), p. 1. It has also been shown experimentally that rhythmic structures serve a principal function in the perception of melodic similarity (Casey, M., Velkamp, R., Goto, M., Leman, M., Rhodes, C., & Slaney, M., (2008), p. 687). This view is apparently not held in some legal circles in the context of music-copyright infringement resolution. According to Cronin, C., (1997–1998), p. 188, "For federal courts at least, originality—the *sine qua non* of copyright—in music lies in melody." He quotes from the case of *Northern Music Corporation v. King Record Distribution Co.* that "Rhythm is simply the tempo in which a composition is written."
- 16 Jones, I. M., (1937), p. 245.
- 17 Sachs, C., (1952), p. 384.
- 18 Hasty, C. F., (1997), p. 3.
- 19 Beament, J., (2005), p. 139.
- 20 Kauffman, R., (1980), p. 393.
- 21 Berry, W., (1985), p. 303.
- 22 Berry, W., (1985), p. 33.
- 23 Kolinski, M., (1973), p. 494.
- 24 *Ibid.*
- 25 Abdy Williams, C. F., (2009), p. 24.
- 26 *Ibid.*
- 27 *Ibid.* It is clear that Aristoxenus considers rhythm as a general phenomenon that is not restricted to music, but also includes speech and dance, among other "things".
- 28 *Ibid.*
- 29 *Ibid.*
- 30 *Ibid.*
- 31 Mathiesen, T. J., (1985), p. 161. The word "chronoi" in this definition refers to a duration of time.
- 32 D'Indy, V., (1902), p. 20. Also quoted in Mocquereau, A., (1932), p. 44.
- 33 Hollos, S. & Hollos, J. R., (2014), p. 7.
- 34 Langer, S. K., (1957), p. 51.
- 35 Percival, H. W., (1946), p. 1006.
- 36 Wright, D., (2009), p. 23. See also Hughes, J. R., (2000), for a review of this book in the context of the interdisciplinarity of mathematics and music.
- 37 Lewis, A. C., (2005), p. 1.2.
- 38 Martineau, J., (2008), p. 12.
- 39 Hall, A. C., (1998), p. 6.
- 40 Garland, T. H. & Kahn, C. V., (1995), p. 6.

- 41 Bamberger, J., (2000), p. 59.
- 42 Clough, J., Conley, J., & Boge, C., (1999), p. 470.
- 43 Cooper, G. W. & Meyer, L. B., (1960), p. 6.
- 44 Levitin, D. J., (2006), p. 15.
- 45 Vuust, P. & Witek, M. A. G., (2014).
- 46 Patel, A. D., (2008), p. 96.
- 47 Parncutt, R., (1994), p. 453.
- 48 Monahan, C. B. & Carterette, E. C., (1985), p. 4.
- 49 Clayton, M., (2000), p. 38.
- 50 Wade, B. C., (2004), p. 57.
- 51 London, J., (2003), p. 277.
- 52 Chashchina, S., (2016), p. 146, ascribes this definition of rhythm to the Russian musicology literature.
- 53 Milne, A. J. & Dean, R. T., (2016), p. 36.
- 54 Arom, S., (1991), p. 202.
- 55 Rivière, H., (1993). Rivière proposes an alternative classification of rhythms in terms of the parameters: *intensity*, *timbre*, and *duration*. See also the commentary by Arom, S., (1994).
- 56 Lowe, C. E., (1942), p. 202.
- 57 Fitch, W. T. & Rosenfeld, A. J. (2016).
- 58 Randel, D. M., Ed., (2003), p. 723.
- 59 Ayres, B., (1972), describes research that uncovers a significant correlation between preferences for regular rhythms and infant-carrying practices that involve bodily contact with the mother. Wang, H.-M., Lin, S.-H., Huang, Y.-C., Chen, I.-C., Chou, L.-C., Lai, Y.-L., Chen, Y.-F., Huang, S.-C., and Jan, M.-Y., (2009), showed that listening to certain rhythms can also change the inter-beat time intervals of the heart of the listener.
- 60 Kaufman Shelemay, K., (2000), p. 35. Koetting, J., (1970), p. 117, is greatly responsible for popularizing box notation among ethnomusicologists, which he called Time Unit Box System (TUBS). Although, Koetting credits Philip Harland, the assistant head of the UCLA drum ensemble at the time, as the originator of TUBS, this notation has been in use in Korea for hundreds of years; see the paper by Lee, H.-K., (1981). The TUBS system notates only the time or duration information of rhythms. This is not a problem for the timelines considered here, where the attacks are almost always isotonic. However, in African drumming the timbre of the drums is also important. Therefore, the TUBS system has been extended by Serwadda, M. & Pantaleoni, H., (1968), and Ngumu, P.-C. & A. T., (1980), to take into account information other than interattack durations, that may be contained in drum attacks.
- 61 Cooper, G. W. & Meyer, L. B., (1960), p. 9.
- 62 Sethares, W. A., (2007), p. 75.
- 63 Dalla Bella, S. & Peretz, I., (2005), p. B66. The nPVI will be treated in more depth in Chapter 17: Rhythm Complexity.
- 64 Cross, I., (1998).
- 65 Cook, N., (1990).
- 66 Redmond, L., (1997).
- 67 Arom (1991), *op. cit.*
- 68 Avorgbedor, D., (1987), p. 4. If there is such a thing as "Western" mathematics, some have argued that its application to non-Western material is a form of cultural imperialism. See Bishop, A. J., (1990) for such a view. I believe there is no such thing as "Western" mathematics. Mathematics is the discovery of *patterns*, and no matter who discovers the patterns, or how they are discovered, they compose the fabric of the universe.
- 69 Prasad, A., (1999). This quotation is part of the answer of John McLaughlin to Anil Prasad's interview question: "How did you go about balancing the mathematic equations of Indian rhythmic development with the less-studied, more chaos-laden leanings of jazz?"
- 70 Agawu (1987), *op. cit.*, p. 196.
- 71 Rahn, J., (1983), p. 33, discusses the problems inherent in three approaches that deal with terminology when analyzing world music: the use of Western terms, the use of non-Western terms, and the avoidance of both, necessitating the introduction of new terminology. Needless to say, all three approaches have their drawbacks. Nevertheless, one may argue that the third approach makes more sense and that the mathematical language is the most objective. Once such terminology is agreed upon, and both Western and non-Western terms may be translated to the mathematical terms on equal footing.
- 72 Agawu, K., (1987), p. 403.
- 73 Honingh, A. K. & Bod, R., (2011, 2005).
- 74 Marsden, A., (2012).
- 75 Wang, H.-M. & Huang, S.-C., (2014) consider the most significant features of rhythm to be "tempo, complexity (regularity), and energy (intensity, strength, dynamic loudness, and volume)."
- 76 Sachs, C., (1953), p. 17.
- 77 Tenzer, M., (2006), p. 33 and Hilleh, M., (2008), p. 88.
- 78 Wiggins, G. A., (2012), p. 111.