

1 **The Syllable is Defined – At Last!**

2

3 **Highlights**

- 4 • Discovery: the definition of the syllable finally found
- 5 • Discovery of an unknown function of oral physiology
- 6 • Discovery: the syllable is not produced by language but by oral mechanics
- 7 • Discovery: The physiological mechanism of alternation runs many body behaviors
- 8 • Discovery: the basis of this physiology is shared with other mammals

9

10 **Abstract**

11 Up to till now the syllable has been judged impossible to define. However, this paper at last
12 supplies the definition and clarifies the problem in defining it. It reveals that the syllable is not a
13 function speech, as it had been intuitively assumed, but the product of a thus far undiscovered
14 aspect of oral biomechanics.

15

16 **Keywords**

17 syllable, definition of syllable, tongue, stress, speech

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19

20 **1 Introduction**

21 **1.1 Defining the syllable**

22 It is puzzling why linguists have not been able to define something as intuitively
23 simple as the syllable. This paper will give the reason for this and it will at last
24 provide a definite definition, also explaining the difficulty met with defining it and
25 why syllables exist in the first place.

26 Non-technical definitions go no further than stating that the syllable is a unit of spoken
27 language (cf. Merriam-Webster), or that it is a single unit of speech (cf. Cambridge
28 Dictionary). Such definitions merely describe its most evident aspect conveying little
29 information, something that is actually not exceeded in the literature. Removed from
30 defining the syllable the research focuses on topics such as syllable structure, the
31 syllable in phonology, the relations of syllables and stress or pitch, syllables in non
32 English languages, its role in second language learning, etc.

33

34 **1.2 The syllable remains undefined**

35 The only studies dealing with this topic published between 1958 and 2013 illustrate this
36 situation: “Stressed syllables are often discussed in phonetic literature. But...the **syllable** is
37 often regarded as a unit which can be apprehended, **but is not easy to define.**” (Ladefoged et
38 al. 1958). “The layman always knows that his language has syllables, but of course **he cannot**
39 **define the syllable...**[and] one is inclined to conclude, paraphrasing Voltaire’s dictum about
40 God, that *Si la syllable n’existait pas, il faudrait l’inventer.*” (**Pulgram** 1970).
41 Few linguistic concepts are at the same time so intuitively clear and so **hopelessly**
42 **elusive as that of the syllable.** The density of research on this notion has grown

43 relentlessly in the last two decades, but apparently this seems to have increased, rather
44 than reduced, the fog surrounding it. (**Bertinetto** 2001). “Human beings have been
45 aware of syllables as essential articulatory units for centuries....While it is obvious that
46 syllables are fundamental to human speech, they have become, as Haugen (1956, p.
47 213) put it ‘something of a stepchild in linguistic description: While sooner or later
48 everyone finds it convenient to use, no one does much about defining it’” (**Ramoo**
49 2013).

50
51 **1.3 (Krakow 1999, Abstract)** relates attempts to define the syllable:
52 The notion that the **syllable is a unit of articulatory organization** has long had
53 intuitive appeal, although a series of studies spanning more than two decades failed to
54 support this hypothesis (cf. Stetson, 1951; Draper, Ladefoged & Whitteridge, 1959;
55 Kozhevenikov & Chistovich, 1965; Gay, 1978; Kent & Minifie, 1977; Harris & Bell-
56 Berti, 1984), etc. [...]Some researchers appeared to give up on the idea that a
57 physiological basis for the patterns would be found or that it was even worthy of
58 further investigation. For example, in his widely cited dissertation on syllable-based
59 phonological patterns in English, Kahn (1976) states that ‘it is an unfair challenge to
60 require hard physiological evidence of syllable organization from those that specify
61 syllables as phonological domains, since it is the nature of speech production to
62 obscure abstract and important units of phonological structure, such as the phoneme
63 and the syllable (pp. 16-17).

64
65 The majority of works on the syllable focus on its various aspects not related to its
66 definition and etiology. (Easterday 2019) speaks of syllabic formations of language:
67 “A speaker’s intuition of what is a pronounceable sequence of sounds is strongly
68 influenced by the syllable patterns of the language they speak.” (**Vazeux et al. 2020**)
69 explores phonemic awareness of syllables:

70 The present study investigates the nature of the spelling-to-sound correspondences taught to
71 enhance phonemic awareness in prereaders. The main assumption in the literature is that
72 learning the alphabetic code through letter-to-phoneme correspondences is the best way to
73 improve phonemic awareness. The alternative **syllabic bridge** hypothesis, based on the salience
74 and early availability of syllables, assumes that learning to associate letters to phonological
75 syllables enables phoneme units to be the mirror of the letters and to become accessible,
76 thereby developing phonemic awareness of prereaders.

77 (Mehler et al. 1981) examines the relationship of segmentation and the syllable. “In
78 this study a monitoring technique was employed to examine the role of the syllable in
79 the perceptual segmentation of words”.

80 (Draga 2007, pp. 161-194) presents an elaborate analysis on the syllable's role in
81 phonology, dealing with its vowel and consonant structures comparing them in a
82 variety of languages: “The syllable has a central role in phonological theory as a
83 constituent that represents phonologically significant groupings of segments [...] The
84 syllable is an abstract phonological constituent without clear phonetic correlates

85 (Ladefoged & Maddieson 1996). Stetson's (1928) chest pulse theory – once
86 considered the standard physiological characterization of the syllable – was shown by
87 Ladefoged (1967) to be largely unsubstantiated". (Cullinan et al. 1977) recounts
88 experimental results via formant behavior in the perception of syllables. "Recent
89 findings indicate that the presence of formant transitions aids the perception of the
90 order of stimuli in repeating sequences of vowels or consonant-vowel (CV) syllables.
91 In this study, 12 listeners reported the perceived order of four vowels or CVs in
92 repeating sequences." A connection between the syllable and its vowel-consonant
93 content is investigated by O'Connor and Trim:

94
95 ...the syllable may be defined as a minimal pattern of phoneme combination with a
96 vowel unit as nucleus, preceded and followed by a consonant unit or permitted
97 consonant combination. All longer sequences are to be analyzed as a succession of
98 syllables, the relative frequency of occurrence of various syllable-initial and syllable-
99 final consonant combinations furnishing a basis for determining the point of syllable
100 division in cases where this is not immediately apparent from the above analysis. The
101 syllable is thus established irrespective of accentual features, though it may
102 subsequently be useful to relate the two together. (O'Connor & Trim 1953, p. 122).

103

104 (Davis & Zajdo 2010) deal with the relation of the frame-content theory to syllables
105 without regard to a definition of the syllable:

106

107 The syllable is a linguistic primitive, a unit found in all languages. It is made up of
108 vowels and consonants which are similarly ubiquitous in the world's languages. These
109 entities are part of the 'starting points' of linguistic and phonetic inquiry. On the basis
110 of their status as 'universals without exceptions,' they are not questioned. They are
111 axiomatically postulated and serve as building blocks in the phonetician's and
112 phonologist's attempts to explain speech and sound structure.

113

114 The above papers represent only a small portion of the literature on the syllable and its
115 various connections to other aspects of speech but they amply document a lack of
116 ongoing interest in the definition and etiology of the syllable.

117

118 **1.2 The initial clue for defining the syllable.**

119 The speech mechanism and its behavior are subject to rules of biomechanics, in which
120 a fundamental behavior is **alternation**, to be outlined below. Alternation means that in
121 a 2-part system first one part executes an action and next the other part executes an
122 action, exchanging functions of the role of prime mover.

123 First however, it is important to show that the device of alternation is recognized as a
124 factor in speech production by three authors, (MacNeilage 1998), (Easterday 2019)
125 and (Stetson 1928), although the specific clue leading to the definition of the syllable
126 is only found in (MacNeilage 1998).

127 The significance of **alternation** is the foundation of MacNeilage’s theory of speech
128 evolution. He relates alternation to exchanges between vowels and consonants which
129 together create the syllable in the context of his frame/content structure. While the
130 present paper significantly augments the function of alternation to reach into several
131 aspects of speech production including the etiology of the syllable, it is useful to
132 consider MacNeilage’s arguments. (MacNeilage 1998, pp. 499–546) proposes three
133 basic ideas for the presence of alternation in speech, underpinning the definition of the
134 syllable stated in the present paper:

135 **a.** “The species-specific organizational property of speech is a continual mouth open-
136 close **alternation**, the two phases of which are subject to continual articulatory
137 modulation. The **cycle constitutes the syllable**, and the open and closed phases are
138 segments – vowels and consonants, respectively. The fact that segmental serial
139 ordering errors in normal adults obey syllable structure constraints suggests that
140 syllabic “frames” and segmental “content” elements are separately controlled in the
141 speech production process” (MacNeilage 1998, Abstract).

142 **b.** Proposing alternation as both the source and etiology of the syllable is supported by the fact
143 that “[e]volution does not build new structures from scratch as an engineer does. Instead it takes
144 whatever is available, and, where called for by natural selection, molds it to new use”
145 (MacNeilage 1998, Section 4.1: p. 503).

146 **c.** Importantly (MacNeilage 1998: p. 506) points out that alternation is a feature of the
147 body’s motor system:

148
149 From this standpoint, the evolution of the mouth open-close alternation for speech is
150 seen as the tinkering of an already available motor cyclicality into use as a general
151 purpose carrier wave for time-extended message production, with its subsequent
152 modulation increasing message set size. However, it has also been pointed out that the
153 open-close alternation confers perceptual benefits. In particular, the acoustic
154 transients, which are associated with consonants and accompany onset and offset of
155 vocal tract constriction, are considered to be especially salient to the auditory system,
156 e.g., (Stevens 1989).

157
158 Analogous notions on the role of alternation are offered by two other authors.
159 (Easterday 2019) similarly writes, in the context of consonants vs. vowels, that “**alternation**
160 between relatively closed (consonantal) and relatively open (vocalic) articulations is fairly
161 regular: syllable patterns such as those in the English words *pillow*, *cactus*, and *tree* are
162 crosslinguistically prevalent.” In a similar vein (Stetson 1928, p. 190) draws a parallel with
163 McNeilage as he considers **alternation** as a fundamental action of the speech tract: “The most
164 obvious thing about the functioning of the vocal tract apparatus is the opening and closing of
165 the vocal tract.” Stetson’s diagram on p. 190 depicting consonantal and vocalic on/off states in
166 the form of square waves, exhibits the opening and closing of the tract as being segmentally
167 temporal relations of hold and release between the two states. It is inferable that alternation
168 does occur simply because closing and opening possess two distinct frames interchanging

169 places in succession.

170

171 **1.3 Alternation in the animal body.**

172 Seemingly removed from the topic of the syllable, it is the action of biomechanical
173 alternation that provides the key to defining the syllable. Therefore it is useful to
174 establish its essentiality in animal, and specifically, in human body mechanics.

175 Alternation is a fundamental mode of physiological action that pervades human,
176 mammalian, and more generally, vertebrate and non-vertebrate body organization.

177

178 Its presence in **protozoan** locomotion underscores the foundational nature of this
179 process. Three types of protozoan movement exhibit **alternation**: in flagellation
180 (Euglena), in ciliary movement (Vorticella) and in peristaltic movement (Acantharia),
181 in all of which a back and forth motion by organelles enables locomotion. Cf.

182 [https://www.notesonzoology.com/protozoa/locomotion-in-protozoa-4-types-](https://www.notesonzoology.com/protozoa/locomotion-in-protozoa-4-types-protozoa/5713)

183 [protozoa/5713](https://www.notesonzoology.com/protozoa/locomotion-in-protozoa-4-types-protozoa/5713). In **earthworms** “Locomotion is...accomplished through the

184 **alternation** of passive extensions and active contractions of successive segments”

185 (Morgulis 1910, p. 616). With **fly larva** (*Chironomus plumosus*, Diptera,

186 Chironomidae) “instead of a longitudinally transmitting metachronal wave of body

187 flexure, a simultaneous arching of the body, combined with the **alternating** use of the

188 abdominal and prothoracic pseudopods as anchorage points, produces a form of

189 locomotion analogous to caterpillar-looping.” Among **lobsters** “the contralateral

190 appendages are able to walk in absolute coordination despite a large speed difference

191 between the two sides (up to 4 cm/s). Under such a constraint, the walking legs alter

192 its invariable parameters...to reach a common step period and steadily maintain the

193 **alternating** pattern (Figs. 6 and 7)”. (Clarac & Chasserat 1986). **Insects** run

194 **alternating** one set of three legs with another set of three legs: “when running, an

195 insect moves three legs simultaneously [...] This is the tripod gait, so called because

196 the insect always has three legs in contact with the ground...”

197 (<https://genent.cals.ncsu.edu/bug-bytes/thorax/locomotion/>).

198 With regard to **fish**, “the usual method of locomotion in fish is now thought to depend

199 on passing **alternating** waves of contraction backward along the body muscles”

200 (Lindsey 1978). **Frogs** typically employ parallel limb swimming and leaping, yet:

201 “We demonstrate that **alternating**-leg swimming is used quite frequently and that it

202 results in a significantly lower velocity to the one obtained by using in-phase leg

203 movements” (Nauwelaerts & Aerts 2002).

204 **Reptiles**, like fish move with body undulation where body sections alternate in

205 direction of inflexion. “Terrestrial snakes, aquatic snakes, and sandfish lizards are

206 observed to adopt different configurations for locomotion, although they all employ

207 the snake-like undulatory wriggling motion,” and in such motion body segments curve

208 **alternately** bend in opposite directions (Zhu et al. 2021).

209 That wing strokes of **bird alternate** between up and down strokes is evidently

210 obvious and thus there are no references to such action in discussing avian wing

211 motions, cf. (Shreyas et al. 2011): “fig. 13: The wing motion of a Painted-stork
212 depicting down-stroke with flat-wing coming down whereas during the upstroke the
213 wings are bent to reduce resistance to upward motion...”.

214

215 **1.4 Human walking**

216 The accomplishment of mature locomotor movements relies upon the integrated
217 coordination of the lower and upper limbs and the trunk. Human adults normally
218 swing their arms and a quadrupedal limb coordination persists during bipedal walking
219 despite a strong corticospinal control of the upper extremities that allows to uncouple
220 this connection during voluntary activities [...] In eight neonates, we found the overt
221 presence of **alternating** arm–leg oscillations, the arms moving up and down in
222 **alternation** with ipsilateral lower limb movements (La Scaleia et al. **2018**, Abstract).
223 (Donker, S. F. *et al.* 2001, p. 87) states:

224

225 They started from the observation (cf. Craik, Herman & Finley, 1976; Webb & Tuttle,
226 1989) that at customary walking velocities the upper limbs swing in **alternation**, with
227 each limb swinging forward and backward in phase with the diagonal lower limb,
228 whereas at lower walking velocities the upper limbs swing in phase at a frequency
229 twice as high as the stride frequency of the legs.

230

231 (Székely 1976) deals with alternation built into neural behavior and indicates that
232 the design of the neural system of limb motion has been shown to operate with **alternation**:
233 “Experimental results that isolated brachial segments are able to control coordinated limb
234 movements, suggest that the motor output pattern is programmed in the structure of the limb
235 segments of the cord. In order to control the *alternating* coordination of a pair of limbs, the
236 limb segments must be in contact with the medulla...” Clearly, both non mammals and
237 mammals cited above employ alternating appendicular movements in one of their modes of
238 locomotion. Within the human body various functions work with alternating steps, such as
239 neural membrane potential (polarization and depolarization), respiration (inspiration-
240 expiration), heart beat (systole-diastole), intestinal movements (peristalsis), walking, running,
241 blinking, mastication, head gestures (affirmation-negation), and so on.

242

243 **1.5 Alternation in speech**

244 In speech alternation takes place along a forward directed serial timeline over which
245 parallel actions of various open and closed apertures are superimposed.

246 Functions in the linear flow of speech arising from alternation include inspiration and
247 expiration during speech, jaw movement, phonational oscillation, consonant-vowel
248 exchanges and as will be shown here, syllabic action.

249 How step-wise alternation in articulation leads toward the stage that creates the
250 syllable can be listed below:

251 In voice production alternation first appears as the oscillation of vocal chords that
252 creates the sound vibrations of phonation. Phonation is superimposed by two slower

253 alternating movements derived from respiration and mastication give rise to
254 articulation, presenting that tongue shapes in speech are consistent with, if not derived
255 from, those seen in feeding, cf. “Rather, we are focusing on those shapes given the
256 hypothesis in the Introduction which suggests that tongue shapes in speech are
257 consistent with, if not derived from, those seen in feeding” (Hiemai and Palmer 2003,
258 Section VII).

259 Articulation produces consonants, vowels and semivowels that typically alternate in
260 opening and fully or partially closing the speech tract as speech progresses, cf.
261 (Stetson 1928) This action then ultimately creates phonemic segments that are
262 traditionally termed **syllables**.

263 **1.5.1** As illustrated in Fig. 000 “Toward generating syllables”, p *****000,
264 the syllable is a structure step-wise built up through consecutively superimposed stages of
265 alternation. Thus, why syllables exist can initially be described as the last stage in successive
266 steps of alternation leading up to speech, as follows:

- 267 a. The process begins using the fundamental intrinsic body function of **alternation**. b.
- 268 Respiration employs this as the two phase alternating cycle of inspiration and expiration.
- 269 c. Respiration develops two additional products of alternation: a) phonation where
- 270 the vocal cords vibrate alternately opening and closing, and b) mastication where
- 271 the jaw alternately moves up and down
- 272 d. Phonation gives rise to vowels that create specific tract apertures and to
- 273 mastication that generates consonants as different tract closures supplying variously
- 274 modulated channels of air in the respiratory tract.
- 275 e. These two actions then produce **alternately** appearing segments of vowels and
- 276 consonants in combinations such as CV, CVC, VC, VCV, etc., as well as vocalic
- 277 diphthongs and consonant clusters.
- 278 f. These distinct segments of vowels and consonant are what generally are
- 279 considered **syllables**.
- 280 g. Additional subfunctions superimposed on syllables, like intonation, stress or
- 281 phrasing are secondary overlays.

282

283 **2 Initial definition and the remaining question**

284 At this point it can be concluded that the syllable is not comprehensively definable as
285 a single unit of speech or some function connected with stress, pitch, phonology,
286 frame-content theory or sound structure, and so on, except as the final stage of the
287 articulation function reached through a sequence of superimposed levels starting from
288 fundamental alternation through ascending levels of various applications of
289 alternation. This is a lengthy and inelegant definition but it does definitely state what
290 a syllable is at a basic level, a function of segmental alternation. The definition also
291 offers a rationale for why the syllable exists: one channel in speech production
292 consists of a sequence of alternations that is automatically generated in which the
293 syllable is an innate natural occurrence.

294 Nevertheless, this definition of the syllable is incomplete because a **question**

295 remains: if a series of alternating functions leads to the syllable, does alternation end
296 at this point or does the syllable itself also operate with some additional form of
297 alternation?

298
299 **2.1** The answer is that the **syllable** indeed also operates with **alternations**, and the
300 basis for this conclusion can be gathered from (Flemming 2003) and (Keating &
301 Lahiri 1993), two papers focusing on the *markedness* in the association between
302 groups of certain consonants and vowels. Flemming states that among consonants
303 “coronals only condition vowel fronting if they are produced with a front tongue body
304 (usually anterior coronals), and only coronals produced with a back tongue body
305 (usually retroflexes) condition vowel retraction” and that “(t)ongue-body position is
306 affected by the position of the tongue tip/blade, because these articulators are
307 physically connected, so each type of coronal has a preferred tongue-body position
308 that facilitates the production of the coronal constriction”.

309
310 **2.2** Clearly as Flemming reports, there are **two** distinct phonologically determined
311 anatomical divisions for coronals because selection of tongue portion is a factor. This
312 implies that in articulation the tongue body is divisible into two parts as Flemming
313 states, into a front and back part.

314 (Keating and Lahiri 1993) describes a study on types of palatals:

315
316 The articulatory data consist of X-ray tracings and palatograms taken from the
317 literature. The acoustic data consist of LPC spectra of brief intervals at stop release
318 and at vowel onset. These data indicate that all of these consonant types are distinct.
319 Contextual fronting of velars is a gradient effect, less extreme than phonemic
320 palatalization of velars. True palatals are **even further** forward on the palate and
321 contrast with contextually fronted velars before front vowels. Thus these consonant
322 types should not be collapsed by feature systems.

323 324 **3 DICHOTOMY**

325 Flemming states that among consonants “coronals only condition vowel fronting if
326 they are produced with a front tongue body (usually anterior coronals), and only
327 coronals produced with a back tongue body (usually retroflexes) condition vowel
328 retraction” and that “(t)ongue-body position is affected by the position of the tongue
329 tip/blade, because these articulators are physically connected, so each type of coronal
330 has a preferred tongue-body position that facilitates the production of the coronal
331 constriction”. Thus as Flemming reports, there are two distinct phonologically
332 determined anatomical divisions for coronals because selection of tongue portion is a
333 factor. Thus, it is inferred from (Flemming 2003) and (Keating and Lahiri 1993) that
334 there is a **dichotomy** in lingual articulating position of palatals, manifesting as a
335 definite contrast in markings in the conditioning of coronal consonants with front
336 vowels, and in the conditioning of velar consonants with back vowels. Dichotomy

337 infers a two part division, in this case of the tongue body and importantly for the
338 present argument, because dichotomy is a basic property of alternation, once more we
339 arrive at **alternation**.

340

341 **3.1 Dichotomic alternations** also turn up in respiration, in mastication and in the brain, cf.
342 (Scharinger et al. 2011) as well as (Sakamoto et al. 2010) cited below.

343 A two phase alternating action occurs in **respiration**: “During expiration, the
344 genioglossus moved posteriorly and during inspiration, it moved anteriorly...[and the]
345 (g)enioglossus moved posteriorly in expiration in two consecutive segments and the
346 airway aperture reduced in size. During inspiration, the genioglossus moved anteriorly
347 back towards its initial position and opened the airway in that plane.”

348 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2652195/>

349 With respect to **mastication**: (T)he hyoid and tongue body are pulled sharply
350 backward and somewhat downward... The bite, pulled back to the level of the last
351 molars, is carried forward and upward toward the first upper molars as the jaws
352 approach minimum gape...[and later] (t)he tongue marker reaches its most backward
353 position...[and then] the tongue continues to cycle forward and then downward”...
354 [importantly, the fact that] “Sagittal tongue cycling is found in all mammals studied
355 with VFG” indicates its presence in the human. (Hiemae and Palmer 2003, p.421.)

356

357 **3.2 Neural evidence for lingual dichotomy in alternation**

358 The presence of the dichotomy in (Flemming 2003) and (Keating and Lahiri 1993) relating to
359 front and back consonants as being independent articulations is reinforced by (Scharinger et al.
360 2011) and (Sakamoto et al. 2010) and both attest neurally determined separations between the
361 frontal and posterior lingual actions:

362

363 In this study, we mapped the entire vowel space of a language (Turkish) onto cortical locations
364 by using the magnetic N1 (M100). We found that dipole locations could be structured into two
365 distinct maps, one for vowels produced with the tongue positioned toward the front of the
366 mouth (front vowels) and one for vowels produced in the back of the mouth (back
367 vowels)...These sets have separate neural representation in the motor network of the speaker’s
368 brain. Articulatory commands may be transmitted over three neural control channels
369 independently of each other (Scharinger et al. 2011).

370

371 The other source asserting a duality in the tongue's connection with the brain is
372 (Sakamoto et al. 2010) This investigation communicates that "Anatomically, the anterior two-
373 thirds and posterior one-third of the tongue are innervated by different afferent fibers (Kandel
374 et al., 1991). Thus, we hypothesize that a difference in brain activity exists in somatosensory
375 processing, depending on the area of the tongue stimulated." It is then concluded that having
376 recorded “the human brain response after stimulating the postero-lateral part of the tongue, and
377 compared it with the antero-lateral part of the tongue...[and we] showed that a difference
378 existed in the somatosensory processing of the tongue, particularly around the SI [primary

379 somatosensory cortex] and ACC [anterior cingulate cortex] (Sakamoto et al. 2010).\

380

381 **4 The Question**

382 Considering **dichotomies** shown by (Flemming 2003), (Keating and Lahiri 1993), (Scharinger
383 et al. 2011) and (Sakamoto et al. 2010) as well as by the lingual frontal and posterior positions
384 in respiration and in mastication (Hiemae and Palmer 2003, p. 421) it may be asked whether
385 these contrasts also manifest as alternation in syllabic action. An affirmative answer is given in
386 sampling English words of one or more syllables, shown below. The results in sampling
387 indicate that alternation does occur with syllables where it takes place involving anterior and
388 posterior parts of the lingual body.

389

390 **4.1 THE EXPERIMENTAL SAMPLING**

391 Since no previous studies have dealt this topic this paper needs to include an experimental
392 survey that researchers are invited to examine. This experiment posts an inquiry whether
393 alternation appears in syllables. The basis of the experiment is built on the facts that as
394 (Flemming 2003) and (Keating & Lahiri 1993) state that the tongue uses its front vs. its back
395 body in association with palatals vs. palato-velars, and as (Scharinger et al. 2011) and
396 (Sakamoto et al. 2010) report that there is a neural dichotomy separating the frontal and
397 posterior lingual actions. The two independently acting parts of the tongue body can provide a
398 field for alternation.

399 The experimental survey will examine whether during articulation alternations involving
400 syllables occur between the dichotomic anterior and posterior lingual body divisions in
401 monosyllabic, bisyllabic and multisyllabic words.

402 To distinguish the anterior and posterior tongue body two symbols are used where the marks
403 show direction like arrowheads: < for anterior placement, and > for posterior placement

404

405 **4.2** To be analyzed is the following random selection of words in which anteriorly and posteriorly
406 articulated tongue parts are marked and it is to be judged if the markings are correct:

407

408 <sew (verb)	421 <o>ffice	434 >af<ter>life
409 >knife (noun)	422 <is>land	435 >ramp
410 <ne>ttle	423 <peo>ple	436 <phone (v)
411 <prin>cess	424 <fear (v)	437 >wil<der>ness,
412 >bread	425 <cri>mi<na>li<za>tion	438 <ir>re<gu>la<ri>ty
413 >once	426 >ne<ce>ssa<ry	439 <o>ran<gu>tan
414 <ten>sor,	427 <coy	440 >hence
415 <or>di>na<ry	428 >bread	441 <un>der<stand
416 >e<gata<ri<an	429 <break (v)	442 >kiss (n)
417 <mist (v)	430 <jour>ney	443 >worm
418 >duck (n)	431 >star	444 <love (v)
419 <good	432 >chore	445 <ad>ven<ture
420 <in>vert	433 <cook (v)	446 <coun>try

447	<la>dy	464	<gar>bage	481	>pe<ninsu>la
448	<wa>ter,	465	<knit	482	<watch (v)
449	>ar<ti>cle	466	<dream (v)	483	<sys>tem
450	>now	467	>bread	484	>strike (n)
451	>con<fu>sion	468	<have	485	<sus>pence,
452	>duck (n)	469	>tree (n)	486	<do>llar
453	>tree (n)	470	<sys>tem	487	>re<demp>tion
454	<thir>ty,	471	<dream (v)	488	>re<vol>ver
455	>di<a>mond	472	>a<venge	489	<do>lley
456	<a>vo<ca>do	473	<di>ver<si>fi<ca>tion	490	<she>perd
457	<a>ve<rage	474	<reed	491	<na>ture
458	<ramp	475	<plant, (v)	492	<pic>tu<resque
459	>then	476	>chore	493	>stil<ted
460	<hea>ven	477	<cir>cum<vent	494	>grass<ho>pper
461	<short	478	>bee	495	>month<ly
462	>bridge	479	<ward>robe	496	<al>ways
463	<ad>ven<ture	480	<ask	497	>pal<mis>try

498

499 4.2.3 The conclusion

500 It is evident that monosyllabic words and syllables of polysyllabic words are spontaneously
 501 assigned to either the front or the back part of the tongue body. Monosyllables are either
 502 anteriorly or posteriorly produced by the tongue. In polysyllables consecutive syllables fall
 503 alternately into front or back lingual positions. This data positively indicates that alternation is
 504 present and integral in syllabification.

505

506 4.2.4 Verification

507 To verify the regular occurrence of alternation in the above sampled words it is
 508 advisable to observe the anterior or posterior lingual locations for each word or
 509 syllable being pronounced while looking at it divided into syllables marked with the
 510 symbols of location. Apparently the visual input has a direct physiological connection
 511 to articulation perhaps deriving from the evolutionary primacy of vision over sound
 512 production. Note that it is essential not to erroneously consider stress in positioning
 513 the syllable.

514

515 5 The final definition of the syllable

516 The definition of the syllable proposed here is neither grammatical nor linguistic but
 517 physiological and is the most fundamental one: the syllable is the terminal stage in the
 518 sequential levels of alternations through steps leading to word articulation. At this last
 519 step syllables are **alternately** allocated to either the **front** or to the **back** tongue body
 520 sections, as discreet segments, and thus syllables are partitions of speech produced by
 521 inherent lingual alternation. This definition does not touch on any of the superimposed
 522 functions the syllable may take on, but it provides a precise designation of what a

523 syllable is. The etiology and the reason for the existence of syllables are, in fact, the
524 same. The origin of the syllable is the ultimate step in articulative and physiological
525 progression—its existence is owed to biological design.

526

527 **5.1 The historical problem for defining the syllable**

528 It can now be understood why defining the syllable as an element in language has been elusive.
529 The syllable is fundamentally not a function of speech but is the product of the physiological
530 operation of alternation as the last step in the sequence of levels into forming and articulating
531 syllables of words. The various roles connected to syllabification are secondary
532 superimpositions over syllables which likewise alternately appear in the anterior and posterior
533 sections of the tongue body. Delimitation, construction, juncture, durations, pitch, stress and
534 other such functions are merely allocated over syllables, and thus the syllable built on the most
535 obvious and readily intuitive rationale have been erroneously considered as either one or
536 several of these overlaid behaviors.

537

538 **6 Discussion**

539 **6.1 Innate lingual alternation.**

540 It is beyond doubt that the tongue mechanism fundamentally operates with **alternation**.
541 This is concludable from its two most basic behaviors of respiration and of mastication where
542 the genioglossus drives the tongue forward and backward. This is accomplished by the anterior
543 genioglossus musculature which **extends** the tongue and the posterior one which **retracts** it
544 towards the hyoid bone (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2652195/>) and
545 (Hiemae and Palmer 2003, p. 421). In syllabic behavior the tongue merely reproduces its
546 innate alternating movements, placing one syllable in the front lingual division and the next one
547 in the back lingual division, and so the definition of the syllable implies that speech itself
548 adapts to inherent alternation in the tongue.

549 **6.2** It can be asked why not place a speech segment repeatedly into the **same** lingual position,
550 in either the front or the back? Because tongue behavior like many other body functions, like
551 respiration or locomotion, requires alternation. Proof of this is obtained when one articulates a
552 segment repeatedly, either in the front or the back tongue body division, during one breath
553 phrase, that is, without breaking the continuity of outward flow of speech respiration: both
554 fluency of speech and speech respiration become **obstructed**.

555 **6.2.1** The syllable may also be phonologically defined as a composite of phonemes that will fit
556 into the framework of the two lingual alternating units and thereby allow fluency. A group of
557 phonemes not permitting such fit cannot be chosen to constitute a syllable. More specifically if
558 the front tongue space is filled with certain phonemes and the back tongue part is not filled with
559 the appropriately matching ones (and vice versa) the word constituted will not be coined. **For**
560 **example** >ta<ble (/ˈteɪ.bəl/) works but artificial words like *<da<ble *(/deɪ.bəl/) or *<ta<kle
561 *(/ˈteɪ.kəl/) do not, similarly “>mo<ney” vs. *>go>ney or *>mo>pey, etc. These substitutions
562 would not exist in the language.

563 **6.2.2** Another way of seeing this is as a balancing scale or as a children’s see-saw with the front
564 or the back tongue parts loaded on either side. The scale will have equal weights on either side

565 only if the syllabic phonemes on either side are appropriate when matched with the other. Thus,
566 the creation of correct syllables is one of the major factor in creating words.

567

568 7 Appendix

569 **7.1** It is observable in the articulation of syllables in the experimental samples, such as
570 >di<a>mond, >wil<der>ness, <a>ve<rage, >grass<ho>pper, >ne<ce>ssa<ry,
571 <a>vo<ca>do that there are syllables between the first and the final syllables which fall
572 in either the front or the back tongue section, however they are biased toward the mid
573 section of the tongue. This bias can be deduced in that if the front or back placement is
574 canceled the syllable settles in the lingual mid section. Thus, within a word
575 intermediate syllables occur in the mid tongue while they also possess secondary
576 front-back alternation. The mid tongue is kinetically controlled by the antagonist
577 actions placed on it by the intrinsic and extrinsic musculature, and can be defined both
578 in geometrical terms and in kinetic terms. In the present topic the it is the latter that is
579 of interest.

580

581 Traditionally the tongue is divided only into two parts. “Human tongue anatomy,
582 while complex, has certain patterns that make it understandable. One helpful way to
583 visualize the human tongue is that it is composed of two basic parts. A wedge shaped
584 GG in the midline separates the tongue muscles into two longitudinal masse” (Sanders
585 2014). “The anterior two-thirds...is visible in the mouth, and the posterior one-
586 third...extends into the oropharynx” (<https://anatomy.co.uk/tongue>) and it is the
587 anterior two-thirds that is considered as the main organ of articulation. In turn this
588 two-thirds section is considered to be of two parts, the blade (or tip or apex) and the
589 body of the tongue and this two-part section is the region studied by (Flemming 2003)
590 and (Keating & Lahiri 1993). However the recognition of a threefold tongue division
591 is essential in analyzing articulation. This was in part done by (Perkell 1969) and
592 (Öhman 1966).

593

594 **7.2** Perkell aptly maintains the physiologically based fact that each consonant, taking in both
595 coronal and velar varieties can occur in different **three** positions. This important point
596 currently not much considered is emphasized by Perkell:

597

598 “We may probably regard the tongue as three separate articulation systems that share some
599 muscles. The three systems may be controlled in a purely independent manner” (Perkell 1969,
600 p. 52)...(C)onsonant production...as in the case of vowel production, the tongue body... must be
601 positioned to enable a particular part of the tongue...to accom[lish the spedific articulation [...]
602 (F)or example, the /k/ in the utterance /i'ki/ is palatalized, and /k/ in the utterance/u'ku/ is
603 velarized. However, both /k/'s are articulated by a combination of movement of the tongue
604 toward the place of articulation with a superimposed deformation of the central portion of the
605 tongue to complete the closure” (Perkell 1969, p. 65). The existence of such three positions of
606 consonants was also asserted by Öhman: “The production of the vowels and of the apical and

607 dorsal consonants involve activity in three (probably partly overlapping) sets of muscles. These
608 sets have separate neural re[presentations in the motor networks of the speaker's brain".
609 (Öhman 1966, p. 62)

610

611 **7.3** The term "central portion of the tongue" needs consideration. The front, back and central
612 lingual sections constitute the **three** active parts of the tongue. Perkell, Öhman and others view
613 this configuration merely as a superimposition on a centrally set tongue without realizing that
614 this behavior supplies a system of consonant articulation which operates in three lingual
615 positions, frontal, central and posterior, as a united function of the oral mechanism. Papers
616 deliberating whether certain consonants are more palatal or more velar overlook the simplicity
617 evident in the so far unestablished fact that precisely like vowels consonants are articulated in
618 distinct front, central and back positional settings. For instance in the case of the velar
619 consonant /k/ they speak of /ki/ as being fronted velar and of /ku/ velar as being backed. This
620 approach is artificial and it is technically simpler, as well as more correct, to speak of front,
621 central and back /k/s, exactly as with front /a/, central /a/ and back /a/, respectively, as in "car",
622 "bar" and "tar". This agrees with (Keating 2003) and (Keating & Lahiri 1993) in that "velars
623 before back and before front vowels, palatalized velars, and palatals...these consonant types are
624 distinct...[t]rue palatals are even further forward on the palate and contrast with contextually
625 fronted velars before front vowels. Thus these consonant types should not be collapsed by
626 feature systems".

627

628 **7.3.1** The mechanics of consonants articulating in **three different locations** is
629 explained by noting that consonantal articulating positions, in exact analogy with the
630 vowels, are determined by choice of the agency of various internal and external
631 muscles of the tongue. This point is affirmed by Perkell (1969, p. 52): "we may
632 probably regard the tongue as three separate articulation systems that share some
633 muscles. The three systems may be controlled in a purely independent manner."
634 The muscular mechanics for such three articulating settings is well understood as the
635 action of extrinsic lingual muscles. Fronting is primarily executed by the genioglossus,
636 centrality by the opposing external muscles, the genioglossus and hyoglossus against
637 the styloglossus, producing equal forwarding and backing, while backing is served by
638 hyoglossus and the posterior genioglossus. Note that the genioglossus can impart both
639 forward and backward forces. Elevations and depressions of the tongue are
640 accomplished by the palatoglossus and the styloglossus in opposition to the
641 hyoglossus. The actions of the three pharyngeal muscles also bias elevation and
642 depression. These muscles which determine tongue positions generate **three**
643 **equilibrium** resting positions for consonants, where they will readily connect with
644 symmetrically positioned vowels. That two opposing forces create an intermediate
645 meeting point, their center of mass, is basic physical and astronomical fact. These
646 positions are stable and are maintained without noticeable strain as experienced in
647 **respiration, mastication and speech**. Recognizing this behavior obviates use of
648 unnecessary classification and terminology. Any consonant in any of its articulatory

649 regions can be produced and be connected to vowels of corresponding positions. In
650 this manner “b” in /bi/ will be the frontal variant of /b/ as in “bitumen”, “b” in /bo/
651 will be the central variant as in “board” and “b” in /bo/ it will be the posterior /b/ as in
652 “bovine”. Similarly, for the “g”s in “giddy”, “guard” and “indigo”. Labeling a
653 consonant in one of its three positions may be denoted with superscripted initials, as
654 for instance, /^fb/, for anterior /b/, /^cb/, for central /b/, and /^bb/ for posterior /b/.

655

656 **7.3.2** (Flemming 2003) and (Keating & Lahiri 1993) recognize only front and back
657 lingual placements without reference to the central one. This is explicable in that
658 positions within or approximating the **central** division are easily misperceived as
659 fronted or backed types of front and back consonants. The central lingual section,
660 mentioned by Perkell (1969, p. 63) as the “semirigid tongue body”, is a
661 kinesiological merger of various near equal percentages of front and back extrinsic
662 lingual muscles. Vowels are assigned to front, back as well as to the well
663 established existence of central positions. Central vowels are those that
664 approximate the center but are not its exact residents. In English the closest to
665 being the actual central vowels are the are /ə/and /ʌ/. Actually an actual central
666 vowel cannot exist in speech because such a point is the mid central anchoring
667 point of the tongue around which its forces move and shape the tongue.

668

669 **7.3.3** The absence of consonant mapping paralleling that of vowels implies that an
670 important aspect of lingual structural behavior has not been investigated, namely
671 that the tongue can take **three** major **equilibrial** settings, as it does in respiration,
672 mastication and speech. Inarguably one can continuously engage in each of these
673 three functions and as with vowels continuous effortless repetition of consonants,
674 except for stops, is possible. In the production of phonemes the additional lingual
675 position subsettings in each function also include fronting, centralizing and
676 backing the tongue.

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