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Quantum Words and Newtonian Sentences, Structure of Language and Algebra

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Abstract: *Language and algebra take their structure from two laws in physics; and algebra is a subset of language. 1) Through its property of discreteness, words take their structure from the quantum property of matter, where phonemes are digits, words are numbers, and the phoneme chart is a periodic table. 2) Sentences take their structure from Newton's 'equal and opposite', where the rudimentary equation 'A equals B' is a symmetrical sentence in which 'A' and 'B' are Nouns, and 'equals' is the Verb: Noun-Verb-Noun. Algebra is a mirror of physics because 'A=B' is a manifestation, in symbols, of a law in physics, where 'A' and 'B' are 'equal and opposite' to one another. The evolution of biological objects, such as an eye or a wing, is governed by formulas in algebra, which represent physics, and do not, themselves, evolve. Language emerges from the same source as the formulas, not the material objects. The modern Subject-Verb-Object S-V-O Sentence is an asymmetrical modification of an archaic, symmetrical Noun-Verb-Noun Sentence. Mediated by the right hand acting as Subject+Verb, when the Sentence became asymmetrical, it carried the brain with it. Modern Sentences are historical modifications of S-V-O. Unmotivated in the historical process, the passive voice is in a class by itself, and may be an outright invention –and the shibboleth that killed the Neanderthals.*

Keywords: Algebra; discrete; equal-and-opposite; equation; gene; language; Neanderthal; particulate; physics; sentence; speech; words

Introduction

The oldest, profoundest mystery in all of science and philosophy is that of the human being. Who are we? I will address that question later. For now, I will address, without justification, the question of equations and sentences. When we know what equations and sentences exactly are, we will be in a better position to consider the question of language, mind, and the human being. In order to understand how things work, it is not enough to examine them from the outside in. We must imagine them from the inside out, in other words, how they develop from first causes –and this is nowhere more true than for language and mind.

In much the way that we would like to know how life emerged from something that isn't life, we would like to know how language emerged from something that isn't language. The

continuing development of language may have been driven by natural selection after the first words and sentences were already in place, but the real mystery is the original structure of the word and of the sentence, and the mechanisms that generate those structures in the first place. By pursuing, to its limit, the scientific study of language, we can discover the laws that generate speech-sounds ("*phonemes*") and sentences, and the support-systems that maintain them. Very briefly, then:

Definitions: Language consists of words and Sentences.

Words are generated under the particulate principle (Abler, 1989), of which the quantum property of matter is a corollary.

Sentences, in modified form, are Newton's *equal and opposite* expressed in the form of symbols. Equations are sentences.

Once we have reconstructed the beginnings of language, we will then be in a position to reconstruct events in its further development.

While the number of potential sentences is surely unbounded, it is only an infinitesimal fraction of the total number of potential word combinations. The concept of a "discrete combinatorial system" or of "discrete infinity" is thus inadequate to characterize the sentence. Instead, we possess an internal mechanism that generated the first sentences, and that still participates in the production of sentences. The point, then, is to identify that mechanism.

I proceed on the principle that physics is more basic than chemistry, that chemistry is more basic than biology, and that these three systems form a natural hierarchy under which a more derived system can not over-rule the laws of a more basic one. Thus living things circumvent entropy not by violating the laws of physics, but by exploiting the discreteness property of the gene. In very exact and specific ways, language, too, is determined by the laws of physics. We seek, here, a theory, rather than a description of language. In other words we can no longer content ourselves with naming and describing the components of language. Instead, we must now show why language has the components that it does have, and the laws that determine their structure and their interactions. I gained a purchase on language by asking, *What is the absolute simplest property of language?* The answer, the discreteness property of the phoneme, was the critical step into abstraction and universal law.

Discreteness and new or emergent properties

In a kind of figure/ground reversal, the point is to stop using discreteness as a description of some specific system, and to isolate and identify discreteness in its own right as the critical necessity for any system with new or *emergent* properties –and to show why discreteness is critical for the production of such properties. In other words, to elevate discreteness from the level of description to that of theory. Using different vocabulary and different logic, the discreteness of the modern *atom* has been known since about 1805 (Thackray, 1972, 76), the *particulate* gene since 1930 (Fisher 1930, 1), and the *discrete* phoneme since 1951 (Harris

1951, 20, 27, 34, 367; Hockett 1960, 1963, 8; Jakobson 1970, 444; Hauser, Chomsky and Fitch 2002, 1571). The gene-language analogy (both systems are strings of discrete units) has been an officially recognized mystery since at least 1966, the centennial of Mendel's first paper (Beadle and Beadle 1966, 44-48, 207; Jakobson 1970, 437-447). A definition of the word *discreteness* is not a theory of why a property of discreteness is necessary for the production of new properties.

Before publication of a theory (the particulate principle, Abler 1989) to demonstrate its central importance, discreteness was just one more descriptive property among many, and there was no reason to single it out for special attention. Thus language has its own internal power-source, the voice, which works even in the dark; language is discrete; language travels around corners and beyond the range of vision; language has three levels of organization – phonemes, words and sentences; language carries emotional content; you can't speak language, you can only speak a language; language is abstract, and does not somehow resemble the ideas that it represents; language is arbitrary, and any word might carry any meaning; the number of potential sentences, and potential languages is infinite; every human society possesses language in fully developed form; there is no longest sentence. The discrete combinatorial system, or a close paraphrase of it (Harris 1951, 23, 34, 367), had been on the books for nearly forty years without attracting attention. It was the particulate principle that pushed discreteness to the center of the discussion on language. Here, the word *principle* is used in its scientific meaning, *law of nature*.

The particulate principle (Abler 1989, 1) provides that any system with properties beyond those of its original constituents, must be composed of discrete constituents "rather than blending constituents, because blending constituents would form combinations whose properties lie between, rather than outside, the properties of the original constituents". The particulate principle applies to phonemes, words, numbers, atoms in chemical interactions, genes –and uniformly to any system with new or *emergent* properties. It is an abstract property of matter and a universal law of nature. So, it is the discreteness property of the atom that allows sodium and chlorine to combine to form something, salt, with properties beyond anything on the periodic table, rather than something with properties between those of sodium and chlorine. The same is true of any system, such as the formation of words from discrete phonemes, where the combination of, say, *t* and *o* forms something, the word *to*, with properties beyond those of any phoneme.

Vastness

Discreteness permits the production of vast numbers of combinations, each of which has distinct properties of its own. A few discrete units, ten, say, can be combined and re-combined to form vast numbers of combinations (Abler 1989, 4). Ten discrete constituents can be combined into a hundred-thousand different five-constituent combinations.

Levels of organization

Discrete constituents can be combined to form constructions with new geometry (Abler 1989, 2) and new properties. Words are intrinsically different from speech sounds, represented roughly by letters of the alphabet; and molecules are intrinsically different from atoms. The formation of new properties amounts to the formation of new levels of organization, and is one of the points of the particulate principle.

Retrievability

In spite of new properties, particulate constituents can be retrieved (Abler 1989, 3) intact after forming combinations with other discrete constituents. So, phonemes can be retrieved intact after they have been combined into words. That is why alphabetic writing is possible. Atoms can be retrieved intact after forming chemical compounds. For example sodium and chlorine can be retrieved, by electrolysis, after they have combined to form salt. The discrete words can be retrieved intact after they have been incorporated into sentences. Retrievability of words makes Chinese writing possible. Properties of genes can be retrieved in the third generation.

Periodic law

The phoneme chart (IPA 1949, 10) is possibly the most under-appreciated structure in all of science. It allows prediction, a process that is only possible under conditions of order. Language scientists can predict the existence and properties of a previously un-discovered speech articulation by noticing a vacancy in the phoneme chart of a language, in exactly the way that Mendeleev in the 19th century (in Jensen 2005, 164) predicted the existence and properties of gallium by noticing a vacancy in his periodic table. Gallium confirmed the periodic law in chemistry, and comparable power of prediction confirms the periodic law (Abler 1989, 5) in the phoneme chart. See Fig 1. The progression of the same phonetic types along a single dimension from closed to open –Stop, Affricate, Nasal, Liquid, Vowel, repeated three times in the same order at different articulatory heights– confirms the periodic nature of the speech system. Under a periodic system, phonemes function like digits; and words, formed by combinations of digits, function like numbers.

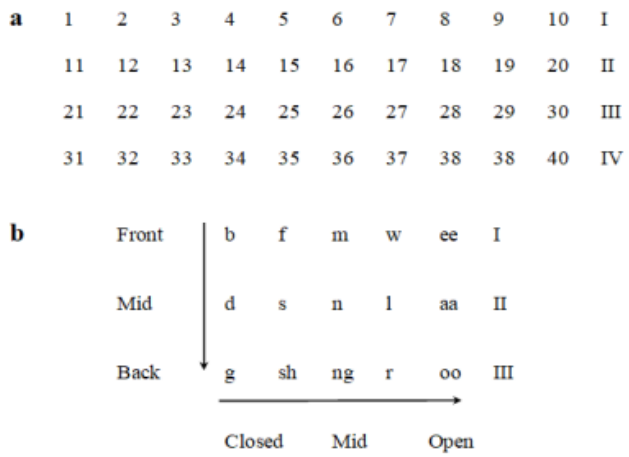

Figure 1. Periodic tables

Periodic systems possess properties that repeat in recurring cycles, or *periods*. a: Periodic table of the consecutive integers, 1-40. Periods I, II, III, IV. b: Abbreviated *phoneme chart*. When the speech articulations are arranged according to their place (Front-Mid-Back) and manner (Closed-Mid-Open) of articulation, their properties repeat periodically. Periods I, II, III. Speech articulations are not phonemes. The discovery of a second naturally-occurring periodic system, that of the speech articulations, allows us to titrate out the role played by periodicity in generating discrete constituents whose properties remain distinct in spite of increased numbers. See text.

The universal status of the particulate principle

The discovery of a second periodic system, that of the speech articulations and their acoustic consequences, offers an opportunity to titrate out the role of periodicity, and discreteness itself, in producing systems with new, or *emergent* properties. How, then, might a natural system generate enough distinctly identifiable constituents, 70 or so, to produce an unlimited number of constructions? If the properties of the chemical elements formed a single physical continuum, as they nearly do in the periods with the lanthanides and actinides in linear order, the elements would not be sufficiently different, one from the next, to be individually identifiable and to generate life. The same must be said for the speech-articulations of human languages. The vocal tract is a tube that has few tricks: It can open and it can close –quickly, slowly, partially, completely– and that's about all.

The solution is a system of coordinates that intersect at right angles. Each coordinate has a small number of *stations* along it, but the total number of constituents generated is the product of the stations on the two coordinates. A 3x3 grid generates 9 constituents, a 3x4 grid generates 12, and so on, up to a limit of 70 or 100 or so constituents. In speech, one coordinate, the *manner-of-articulation* coordinate, has stations that proceed from stops (closed), to affricates, to spirants, to nasals, to liquids, to vowels (open). This series is repeated three times, front, mid and back, following a periodic law. We are merely lucky that

the properties of electrons generate a periodic system capable of generating the dozen or score of elements that are necessary for life.

The properties of the phonemes and of the elements are periodic, even though they are not a continuous function like a sine wave. In other words. there is nothing between the elements (Mendeleev 1901.4, 476ff; 1889 in Jensen 2005, 170), and nothing between the phonemes, a condition known in psychological science as *categorical perception*. The gaps are manifestations of discreteness, and are necessary under the particulate principle. What would happen if there were something between the elements, in other words, if the properties of the atoms formed a continuous spectrum, with no spaces? No two atoms of the same element would be exactly alike, and no two molecules of the same enzyme would be exactly alike. Such enzymes would not fit precisely with their corresponding substrate molecules, and a well-regulated metabolism would be impossible. Here, examination of properties in language has cast unexpected light on a property in physics, not the other way around. This trend will continue.

Speech articulations are not phonemes, but are only the addresses of phonemes. The phoneme itself is one of the profoundest mysteries in all of nature. That is to say that the upper limit to the number of phonemes in a language (70 or 100 or so) is determined by the number of distinguishable speech articulations, not by the concept of the phoneme, which is, in principle, unlimited.

A quantum property

As periodicity is a means of preserving discreteness while still generating as many as 70 or 100 distinctly identifiable constituents, the mis-named *phoneme chart* (better named "the periodic table of the speech articulations") shows that the periodic property is a corollary of the particulate principle, and not a primary law in its own right. The law, or theory, is the particulate principle. In effect, the particulate principle and its consequences –discreteness, combinations, vast numbers, retrievability, new or *emergent* properties, new levels of organization, a periodic property, the empty spaces between the elements and between the phonemes– are the quantum property of matter manifested at a human scale.

In spite of the claim (Pinker and Bloom 1990, 721) that "there is no support for the hypothesis that language emerges from physical laws acting in unknown ways", or from "an undiscovered corollary of the laws of physics" (Pinker 1994, 363), the long-suspected relationship between language and the gene (Beadle and Beadle 1966, 44-48, 192; Jakobson 1970, 437-447) has been verified in the particulate principle (Abler 1989, and above). As Irwin Schrödinger, quoting Max Delbrück, observes (1946, 68-69), "living matter, while not eluding the 'laws of physics' [i.e. entropy] … is likely to involve 'other laws of physics' hitherto unknown".

The particulate principle and its corollaries are exactly those *other laws*. That is to say that it is the discreteness, or particulate property that allows any system to form combinations

without blending and averaging, thus defeating entropy without *eluding* physics. Together with the gene (Fisher 1930, 1) and the atoms, language takes its structure from physics, not biology. We may anticipate that the next breakthrough in physics will arrive as an understanding of how the dimensional properties of matter generate the particulate principle and its consequences at a variety of dimensional scales. The next section concerns the physics that generates the sentence. See Figure 2 below.

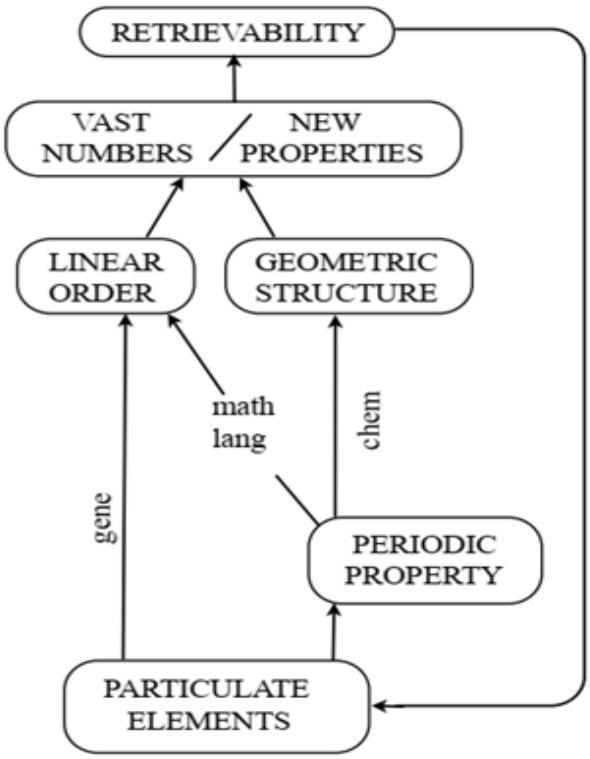

Figure 2. Quantum Property. In the diagram, the particulate principle at-a-glance

In the diagram, derived properties proceed upward, as shown by the arrows. The gene generates vast numbers of new structures by linear ordering of only a few (four) discrete constituents. Language, math and chemistry generate more constituents by generating a periodic table constructed on intersecting dimensions. Language and math, like the gene, are delivered in linear order, while chemistry generates geometric structures. All these systems generate vast numbers of structures with new or *emergent* properties based on discreteness – and in all systems the original constituents remain retrievable after combination. Human existence depends on discrete systems in their several forms. Systems generated in the same way are the same system. Once retrieved, material constituents (atoms, genetic bases) can be re-used. chem: chemistry. lang: language.

The sentence

All theories of the sentence work by what the mathematicians call *assuming the proof*. In one way or another they generate language from language, when the point is to derive language from something that isn't language. Transformational grammar (Chomsky 1957, 61; 1965, 131); generates sentences from *kernel* sentences. Deep-structure grammar (Chomsky 1957, 27; 1965, 65; Langendoen 1969) assigns structural trees to sentences that already exist. Recursive-embedding grammar (Hauser, Chomsky and Fitch 2002) generates sentences from sentence fragments. The concept that a little bit of language is good, and a little more is better, therefore language is subject to natural selection (Pinker and Bloom 1990, 712, 723), applies to language only after language has already come into existence, and is not a theory of language. Steven Pinker explains (1994, 351) that "The first steps toward human language are a mystery" –in other words, the "first little bit of language" remains unknown; yet this first little bit is exactly what we want to know. The rest is the historical process, not the origin of language. A discrete combinatorial system (Harris 1951, 34, 367; Pinker 1994, 84, 85; Nordström 2014; Verhoef, Kirby and de Boer 2015) generates chains of words, not sentences.

Just because language is delivered as a chain, isn't a reason to suppose that language is generated as a chain. A chain of words isn't a sentence, not even if it has the same words as a real sentence, because a chain of symbols is without intrinsic structure, and has no more ability to assign functioning roles to its components –Noun, Verb, Preposition, Adjective, Subject, Object– than the links of an ordinary chain. Thus it falls to the words themselves, in their role as part-of-speech, to generate the functioning interactions that characterize a sentence. Nevertheless, part-of-speech isn't part of words at all, but is actually assigned to words by some un-seen mechanism of the sentence itself. So, we might take a *walk*, or take a *look*, using apparent verbs as nouns. A mechanic might *cannibal* a part from one machine to fix another, or a prospector might *Geiger-counter* a rock, using apparent nouns as verbs. We might have an *in* at the mayor's office, using an apparent preposition as a noun. Tattlers may *out* their victims, or a bicyclist might *kitty-corner* an intersection, using apparent prepositions as verbs. The mystery of the sentence lies not in the identity of the words, but in that of the un-seen mechanism that assigns interactive roles to words that have meaning, but no power of organization. See Figure 3.

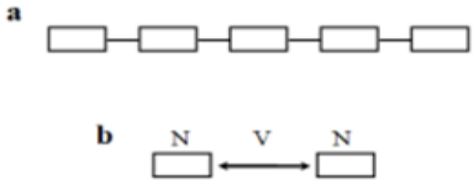

Figure 3. Two incompatible theories of the sentence

Theory a shows the sentence generated by attaching words to other words. Theory b shows the sentence generated by attaching words to the three cardinal components of an event in physics. In theory a, the components are without differentiated structure, and possess no

mechanism for assigning functional roles to one another. Theory b: Newton's *equal and opposite* represented in the form of symbols, shows a dynamic relationship generated among three interacting components –two quantities named *Noun N*, and the impulse named *Verb V* (arrow), that generates the dynamic relationship between them.

The first word in a sequence is not, by virtue of being first, a Noun or a Subject; the second word is not, by virtue of being second, a Verb; and the last word is not, by virtue of being last, a Noun or an Object. These classes and functions are generated elsewhere; and words are later attached to them, as symbols. The organizing mechanism has to stand above the line of words, spanning them.

The solution to the mystery of the sentence lies in the observation that mathematics is a subset of language, that equations are sentences, and that all equations/sentences are modified versions of *A equals B*. Only assertions can be true or false, and only sentences can be assertions. *A equals B* is a simple declarative sentence which asserts that *A* is equal to *B*, and *It is true that A is equal to B*. The word *equals* is an intransitive verb in the third person, singular number, present tense, indicative mood, active voice –and *A equals B* has every qualification to identify it as a sentence of language. See Figure 4. The concepts of sentence, equation, noun, verb, assertion, and truth-and-falsity are aspects of one another, generated under *equal and opposite*. A sentence is a string of words in its delivery only, not in the way it is generated or perceived. It is a dynamic engine that generates relationships among words.

The fundamental theorem of the equation

If we can't analyze *A equals B*, there is no point in analyzing more sophisticated equations – and the mechanism that generates *A equals B* is Newton's third law, *equal and opposite*, represented in the form of symbols. The *A* and the *B* are equal to one another and opposite to one another, and the *equals* says so. In modified form, the mechanism that generates *A equals B* can be conceived as an empty balance-scale where the *A* and the *B* are placed on opposite ends of the beam, and the *equals* represents the fulcrum. The steps in a mathematical proof are judged to be *correct* when each successive step preserves the symmetry established in the previous step. In other words, the expression *A=B* establishes that *A* and *B* stand in a symmetrical relationship to one another; and *A'=B'* is *correct* when it preserves the original symmetry established in *A=B*. This observation may offer an approach to Hilbert's program.

The *equals* relation is not contained in the spoken word *equals*, but is a property of the empty balance-scale, and is merely named by the word. A different word names a different property. Whether expressed or not, the *equals* relation remains active in the expression of truth-and-falsity. See Figure 4.

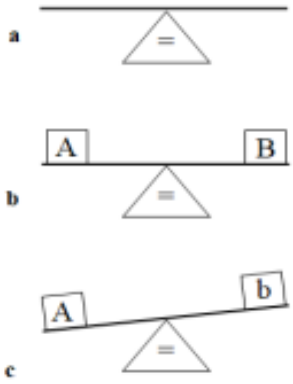

Figure 4. Truth and falsity

a: The empty balance-scale that represents an alternate manifestation of *equal-and-opposite*, both for equations and ordinary sentences. When the quantities placed upon the two ends of the beam are perceived to be at equilibrium, as at b, we experience a sensation of truth. Such quantities may be numbers, generating an actual equilibrium, or ordinary ideas and words, generating symbolic equilibrium. Even rhyme can trigger a sensation of symmetry and of truth. When quantities placed at the ends of the beam are out-of-equilibrium, as at c, we experience a sensation of falsity. Re-conceived after Abler 2010, 413, with permission. See text.

The empty balance-scale represents the assertion, *I am in a state of equilibrium* –and when the *A* and the *B* placed upon the two sides balance one another, for example *2+2* and *4*, this assertion is true. When they don't balance, for example *2+2* and *5*, the assertion is false. The symbols placed upon the two ends of the beam become Nouns, and the symbol placed upon the fulcrum becomes the Verb. It is the hidden balance-scale (Abler 2010, 413) that generates all basic properties of Noun, Verb, sentence, assertion, and truth-and-falsity. An empty balance-scale at equilibrium, then, is the primitive mechanism of all sentences, and the vehicle of assertion, the vehicle of truth-and-falsity, and the primary mechanism of the human mind and brain. Thus anything –even rhyme (Opie and Opie 1959, 61)– that triggers a sensation of symmetry or balance will trigger a sensation of truth. The concept of truth as a congruence between assertion and experience is a relatively recent invention, probably no older than the Greeks, about 500 BC. That is why we revere them. It did not evolve in natural selection because *some things really are true* –a scientific cart-before-the-horse. So, its source must be sought elsewhere. Once a thing is known, it becomes obvious –and we can hardly imagine a time when we didn't know it. Thus we too easily assume that modern structures have always existed as we find them now, and that they must have evolved in natural selection for reasons that are deceptively modern. This rule applies to the equation, the passive voice, the Subject-Verb-Object sentence, and many other modern concepts and constructions.

Why mathematics is a mirror of physics

That a special relationship exists between mathematics and the properties of the material world has been recognized for centuries. Thus Pythagoras (about 550 BC) proclaimed that "All is number"; and Galileo (died AD 1642) stated that "The Book of Nature is written in the language of mathematics". Albert Einstein (1922, 28) carried these observations to a new level by turning them into the question, "How can it be that mathematics, being after all a product of human thought which is independent of experience, is so admirably appropriate to the objects of reality?" And, by observing that, "the laws of nature must be already formulated in the language of mathematics to be an object for the use of applied mathematics", Eugene Wigner (1960, 6) in effect proved that mathematics is a mirror of physics –but without showing why. Max Tegmark's (2014, 318) "The theory that our external physical reality is perfectly described by a mathematical structure while still not being one is 100% unscientific" is a paraphrase of Wigner, and Tegmark's "Physics is mathematics" is a paraphrase of Pythagoras. Neither is a theory of why mathematics is a mirror of physics.

Another view of mathematics comes from Reuben Hersh (1997, 248-249), who explains, "Mathematics is like money, war, or religion – not physical, not mental, but social. … Its most salient special feature is the uniquely high consensus it attains." I point out that, under *equal and opposite*, each side of an equation responds to changes in the other side only, not to changes in the social situation in which the equation finds itself. Equations, at least, are thus self-regulated, more found than made, and not socially determined; and the most overwhelming consensus, for instance, can't make the value of pi equal to 3.

Lakoff and Núñez (2000) use the concepts of *equation* (page xiv) and *true* (pages xiv, xv, 341) as axiomatic, when these are precisely the concepts that demand analysis. They continue (378), "It is the human capacity for conceptual metaphor that makes possible the precise mathematization and sometimes even the arithmetization of everyday concepts – concepts like collections, dimensions, symmetry, causal dependence and independence, and many more. … (379) The portrait of mathematics has a human face." Arithmetization and mathematization are not the question. The question is the laws that generate number, the equation, assertion and sensations of truth – used but not reduced to theory by Lakoff and Núñez.

Everything about our current social structure converges to persuade us that mathematics is an autonomous system that is somehow given, or simply just *there*. Thus we have mathematicians, math prizes, Departments of Mathematics, history of mathematics, math prodigies, math geniuses –and we are fond of telling one another, *You do the math*. The math.

Equations are a mirror of physics because both systems are generated under the same laws. Numbers and words, genes and atoms, are generated in physics under the particulate principle; and equations and sentences are generated in physics under equal-and-opposite (Abler 2005, 181; 2015, 31). Out of the many-thousand-year history of mathematics (Robins

and Shute 1987, 11), it is only in the past half-millennium, with the invention of the equation and the equals-sign by Robert Recorde (Boyer and Merzbach 1991, 290) in AD 1557, that it has even been possible to see mathematics as an autonomous system that functions on its own. The mathematical works of Euclid (possibly leaked from Pythagoras), Archimedes and al-Khwarizmi were written in ordinary prose. Mathematics is no more separate from language than the embedded clause or the passive voice. An equation on paper is a written text that can be read out-loud as speech. The same can be said of language, and of nothing else.

Mathematics has such a small vocabulary that each word can be assigned its own distinct symbol, furthering the illusion that mathematics is somehow its own autonomous system. It isn't. It is language generated by physics. Mathematical symbols have exactly the same status in perception as Chinese characters (Abler 2005, 69). The equation is a modern manifestation of the original sentence mechanism, lingering in the brain in its original form. See Fig 5. Nature just doesn't have the same Departments as a university.

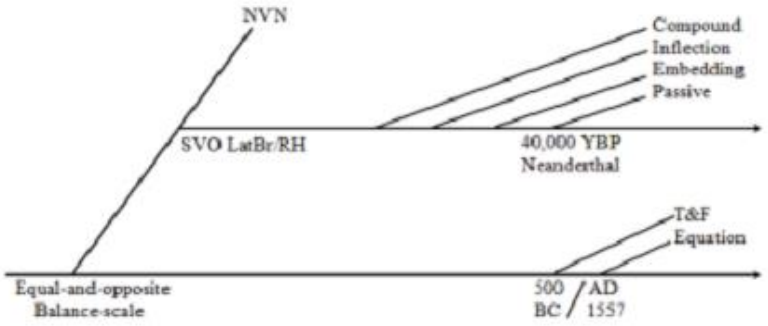

Figure 5. Genealogy of language structures

Linguistic and brain structures emerge from Newton's *equal-and-opposite*. *NVN*, symmetrical *Noun-Verb-Noun* sentence, no longer in use. LatBr/RH, lateralized brain and right-handedness emerge as a consequence of asymmetrical SVO Subject-Verb-Object sentence. Other linguistic structures emerge from SVO sentence. Only NVN is basic. Invention of passive voice provides shibboleth leading to death of Neanderthals, and the dating of a linguistic construction, 40,000 YBP, Years Before Present. T&F, modern concept of Truth and Falsity, 500 BC. Equation *A=B* invented AD 1557 from the same mechanism that generated the primitive NVN sentence. See text.

The evolution of language?

The fundamental mistake in unraveling the origin of language is that we have treated sentences and equations as if they were primary material objects in themselves. like a wing or

an eye, and that, if they are related, they must have some kind of ancestor-descendant relationship. As we will see, equation and sentence are related because they are generated independently from the same substrate in the brain. The profile of a bird's wing (Pinker 1994, 347) might evolve in natural selection in conformity to a law expressed by the formula for an airfoil, or the eye (Pinker and Bloom 1990, 710, 712; Pinker 1994, 349) to the formula for a sphere. But the formula expresses a law in physics. It specifies a process in evolution, but doesn't itself evolve.

There is no boundary between equations and ordinary sentences, and the structure of language emerges from the same source in nature as the formula, not the material wing or material eye. The structure of language didn't evolve in biology any more than *equal and opposite*, or *A-squared plus B-squared equals C-squared*; and quantitative theories of language evolution (Nowak et al. 2000, 2001) are moot. The concept that *a little bit of language is good and a little more is better* is, at best, a theory of post-origin development, not a theory of language or of language origin. Borrowing a rule from biology, the less differentiated structure precedes the more differentiated one. That is to say that the theory in physics precedes that in biology; and the "pitiless laws of physics" (Pinker 1994, 364) do in fact generate the structures and relationships of language.

Sensations of language and mind

The whole point of Western philosophy has been to make assertions, and to show whether they are true or false. We use mathematics as a model of the material world. We measure nature and seek truth. But the more basic question (after Abler 2010, 412) is, what is an assertion, and where do we get our sense of truth-and-falsity? Rather than describing sentences, or finding the next more sophisticated equation, we have asked, what is an equation, and what is a sentence? Sentences and truth seem real because they are sensations, like sensations of color or of tone. They are exactly as real as, say, green, or A-440. The difference is that sensations of tone and of color correspond to events outside the body – wavelengths of light, or of air-pressure disturbances– which can be identified by experimental demonstrations. *A equals B* predicts that there is a physiological balance-scale hidden somewhere in the brain –whether in mechanisms of mirror neurons, or arrangements of cellular microtubules, or even the symmetrically-placed points of a water crystal concealed between membranes inside the nucleus of nerve cells (Abler 2010, 423). Working from a suggestion by Albert Szent-Gyorgyi, the discoverer of vitamin C, Andrei Sommer and colleagues (2008) have shown that such crystals are possible. The balance-scale theory will be verified when the physiological balance-scale is found in its hiding-place somewhere inside the brain.

The introduction of Subject-Object to the sentence

Once we have a clear theory of language and its beginnings, we can reconstruct events in its development. The earliest sentences, then, were syntactic, with functioning Noun and Verb. But they were symmetrical, and ambiguous, and lacked a means of expressing the asymmetrical Subject-Object relation that is now universal in language. So, *John loves Mary*

and *Mary loves John* were symmetrical, ambiguous and the same for exactly the reason that *A=B* and *B=A* are symmetrical and the same. Here, I am asking the reader to do the near-impossible – to shed knowledge of meaningful word-order in the modern Subject-Verb-Object sentence, and to revert to the archaic, symmetrical *Noun-Verb-Noun* sentence, where word-order is as meaningless as it is in *A=B* and *B=A*. It is a little like un-hearing a song, but it must be done.

Subject-Object (S-O) is so ubiquitous in our everyday experience, and the ability to express it so valuable, that *S-O* is worth incorporating into the sentences of language, our most powerful medium of communication. All theories of the sentence based on universals or observation have failed and will continue to fail because the modern *S-O* sentence is universal but neither basic nor original; and no examination of it, as found, will reveal the structure of language.

The earliest sentences were short, probably three words corresponding to the three components of the balance-scale to which they were attached. With its recognizable beginning, middle and end, the primitive sentence possessed un-used resources that could be assigned functional roles. The assignment of functional Subject and Object to the first and last words of the primitive sentence produced the modern sentence by making word-order meaningful and syntactic. Word order is minimally meaningful in the *N-V-N* sentence, in designating part-of-speech. *S-V-O* extends meaningful word-order to designating a relationship between two examples of the same part-of-speech.

The instrument of incorporation was the hand. Attached to each other anatomically (Crosby, Humphrey and Lauer 1962, 516), language and the right hand –just the right one– are the Siamese twins of neuroanatomy: Any theory of one is necessarily a theory of both. The hand-language connection is still to be seen in everyday experience, as a kind of behavioral fossil. Thus David McNeill (2002, 6, 17) has found that gestures of the hand correspond to ideas in spoken language, and may even be syntactic. And a small number of gestures, now generalized to cover the entire body, stand as proxies for spoken sentences. About thirty-five of these would be recognized (Abler 2015, 28) in America: Holding out a thumb to indicate *I want a ride*, or shrugging the shoulders to indicate *I don't know* or *I don't care*, or winking an eye to indicate *We understand each other*.

In the earliest moments of language, then, the symmetrical sentence received an expressive supplement from the hands acting as puppets –one hand playing the role of Subject-plus-Verb, the other playing the role of Object. Why the right hand was selected, rather than the left, as the standard for expressing the Subject-Verb combination may remain forever a mystery. But through the agency of the hands, the asymmetrical Subject-Object relation was incorporated into the sentence by making word-order meaningful; and lateralization, or asymmetry, was incorporated into the brain.

I am suggesting a gestural supplement to spoken language, not a gestural theory of language origin (Hewes et al. 1973; Gillespie-Lynch, 2017), which shifts the mystery of language from the mouth to the hands without solving it. With the emergence of S-O, language came into

its own as an autonomous system, exhibiting properties that were unique to itself, and could not happen in any other system.

The sentence invasion of voluntary movements

The hand-language interaction initiated what might be called a sentence invasion, starting with the hands, in which voluntary human movements were transformed into proxy sentences, with their power of assertion, experienced by us as deliberate intent, and property of truth-and-falsity, experienced by us as good-or-bad. With the sentence invasion, our primate ancestors were transformed into human beings.

The sentence invasion marks the beginning of language and the human being as we know them. As far as I know, subsequent developments in language were a matter of the historical process in language change, which does not involve genes, and is not a matter of biology. In the earliest moments of language, then, the number and diversity of syntactic structures increased under the historical process, not under organic evolution. We have twice, now, mistaken the historical process for organic or psychological processes. Once in 1957 (Chomsky 1957, 61), with linguistic transformations, and again in 1990, with "a little bit of language is good and a little more is better" (Pinker and Bloom 1990, 712, 723). Any parallel or convergence with biological evolution is due to the shared physics of the particulate principle, which allows beneficial changes to accumulate without violating the laws of physics.

Creative technology

Creative technology is a manifestation of geometry and physics. Human technology can only be a by-product of the geometry and physics corresponding to equations, experienced subjectively as the mind's eye (Abler 1973, 109), and imposed on the outside world as an assertion carried out by the hand.

Consciousness

Consciousness (Abler 2015, 32) is the subjective experience of self-observation, mediated through the mind's eye. It is the awareness of the balance-scale of the sentence in all its proliferations simultaneously –assertion, truth-and-falsity, deliberate action, good-and-bad. Even beauty, which has its beginnings in the symmetry for which it is still sometimes mistaken.

Derived structures in language

After the incorporation of syntactic Subject-Object into the sentence, other syntactic constructions emerge as modifications of existing ones. All are useful, none is basic. In other words, all could be eliminated from the world's languages, and we would still be left with something that could legitimately be called "language". Embedded clauses are reduced

sentences, and are not basic. Thus Everett (2005) has found empirically what can be shown in principle.

Word compounds are reduced sentences, where one word plays the role of Verb. Some compounds are generated as compensation for emerging homonymy, as when *stick-pin* and *ink-pen* emerge to compensate for homonymy of *pin* and *pen*. Adjectives are reduced verbs with *is*.

Linguistic tone (Hyman 1973) emerges as compensation for reduction of consonants at the end of words. The imperative is a modified form of the future tense: *Thou shalt not kill; Thou shalt not steal*. Word-endings are compounds which can drive out word-order (Abler 2013, 55) as an indicator of Subject and Object. Other features of language proceed directly from the structure of arithmetic (Abler 2005, 37).

Prepositions have the same fractal (Mandelbrot 1983) syntax (Abler 2010, 418) as arithmetical operators "+", "-", "x", "÷". Ellipsis, the use of a word more times than it is expressed, is a synonym for the distributive law, where *John built a house, a barn and a shed* or *John built a house, and John built a barn, and John built a shed* is generated by the same mechanism that generates *ab+ac+ad* from a(b+c+d). Linguistic ambiguity, where the same expression has two different interpretations, is also a mirror of arithmetic. Thus the classroom example *red cars and trucks*, which can mean either *trucks and red cars* or *red cars and red trucks* is generated by the same mechanism that generates *(2x3)+4=10* and *2x(3+4)=14* from *2x3+4*. More complex syntactic structures, both in equations and in ordinary sentences, are generated by fractal duplication. See Figure 6. These include indirect object and prepositions, as well as arithmetical operators.

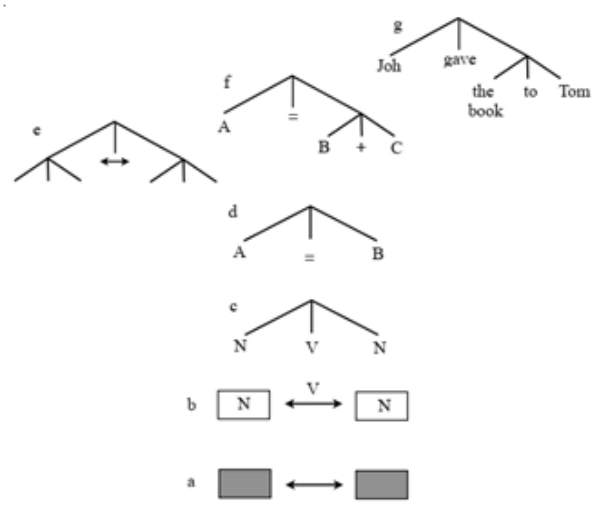

Figure 6. Fractal derivation of complex equations and sentences

a: *For every action there is an Equal and Opposite reaction (E&O)*: The double arrow represents the impulse that generates action and reaction in two opposite bodies. b: *E&O* represented by Nouns *N*, and impulse (double arrow) by *V*, the Verb *equals*. c: *E&O* represented as a structural tree. d: The structural tree represented as symbols. e: sentence fractal, the structural tree of the sentence extended in fractal form. f: the equation *A equals B + C* generated under the sentence fractal. The tree stops growing where a symbol is attached. In the equation, the equilibrium relation is expressed as the *equals* relation, "=". g: Prepositions of language are generated under the same fractal mechanism that generates the arithmetical operators +, -, x, ÷. Sentence, *John gave the book to Tom*. See text.

In an extension of what Liberman, Cooper, Shankweiler and Studdert-Kennedy (1967, 441) have called the *speech mode* of auditory perception, I suggest that the sound of the speech-signal summons forth, in the listener, the balance-scale of the sentence. Listeners then reconstruct a speaker's intended sentence by attaching the incoming words to their own internal balance-scale, not by attaching the words to one another. All of language and languages is/are generated under a single source. But that source consists of two laws in physics, not the innate UG, or Universal Grammar postulated in biology by Chomsky. While there is more to mathematics than equations, and more to language than sentences, a theory of language without a theory of the sentence –like a theory of mathematics without a theory of the equation– is incomplete. Under the theory adopted here, a formative law in physics, *equal and opposite*, when represented in the form of symbols, *A=B*, generates power-of assertion, property of truth-and-falsity, and categories of Noun, Verb and Sentence. That is to say that the formative relationship in the transfer of energy generates the formative relationship in the transfer of information. As with the chemical elements, or even the solar system, an appearance of design in nature (Pinker and Bloom 1990, 710, 726; Pinker 1994, 360) does not inevitably indicate natural selection –and there is more to choose between than natural selection and God.

Uses of language

Last, we come to the practical use of language in the beginning of the modern era. All laws, both human and natural, declarations, certificates, judicial sentences, oaths, commands, lies, threats and promises, are sentences and assertions. Laws and common prayers and songs are exact quotes (Abler 2005, 106), and have to be –made possible by the particulate principle. Quotes require discreteness for the same reason that enzymes requite discreteness: Exact duplicates would not be possible without it, and laws would be changeable and unreliable.

The jewel in the crown of language, and death of the Neanderthals

Routinely criticized for being 'weak', the passive voice is banned from some publications and discouraged in others. While passive *The apple was eaten by the worm* may seem weak in comparison to its corresponding active *The worm ate the apple*, the passive voice nevertheless finds powerful uses, especially where the Subject is obvious, or the Object is more important. So, the passive "*Routinely criticized for being weak, the passive voice is banned …*" is clearer than its corresponding active, "Some people criticize the passive voice

for being weak, and ban it …". Even the hyper-colloquial *We was robbed!* is more effective than the more correct *We were robbed!*, not to mention the active *Someone robbed us!* And the poster *English spoken here* is clearer and maybe even kinder that its corresponding active *We speak English here*. The passive is to language what the knight is to chess –subtle but powerful.

Neither original in language, nor obviously derived as a replacement for something that might have disappeared, the passive did not arise in the natural course of language change. It is in a class by itself, and probably the outright invention of some forgotten stone-age shakespeare. In its day, the passive voice would have spread like a virus of prestige, with one speaker infecting the next (Opie and Opie 1959, 5, 58) throughout the community of speakers. With its reversal of Subject and Object, the passive can not be pantomimed with the hands, i.e. the *Verb+Object* combination can not be pantomimed by one hand. The passive thus calls for some purely linguistic dexterity, and may have been the shibboleth that killed the Neanderthals. Thus it would have been easy to invent a kind of stone-age IQ test such as *Say 'The apple was eaten by the worm'*. And when the Neanderthals mumbled, or fumbled with their hands, they were exterminated, one by one, and in groups. The Neanderthals had language, but when the passive voice pushed language into the realm of the abstract, the Neanderthals couldn't follow. See the time line, Figure 5. It is the suddenness of the Neanderthals' disappearance, with no obvious physical correlate such as a new weapon or decorative art form, after five-thousand years of unremarkable coexistence with modern humans, that suggests a linguistic invention, rather than a product of language change or biological evolution, both of which are notoriously imperceptible. The passive voice shows that the people of the stone age were keenly aware of language, and were good at it. The inventor of the passive voice is my nominee for the earliest individually-identifiable person, and for the most important person who ever lived.

Here, I have done nothing more than what a detective might do in solving a mystery, by seeing how the pieces fit together. The evidence for Neanderthal language isn't a matter of a language gene. It is their sudden disappearance with no other obvious culprit than an invention in language. If the Neanderthals didn't have language, a shibboleth would have been pointless.

Perspective

If correct, the particulate-newtonian theory abolishes darwinian rule, as far as language and mind are concerned –and much of arithmetic and algebra. The kluge hypothesis (Marcus 2008), the idea that language and mind are a conglomerate of un-related bits and pieces thrown together by the accidents of history, dissolves into an artifact of method. The individual study of lateralization, serial ordering, the object-verb relation, hand-use, part-of-speech, language evolution, theory of truth, the gene-language analogy, consciousness, syntactic structures, mathematics, the physics-mathematics connection, creates an impression of complexity. Under the quantum-newtonian theory, complexity dissolves into proliferations and ramifications of properties generated under two simple laws in physics.

The quantum-newtonian theory represents universally accepted science, and will be verified when the physiological balance-scale is found in its hiding-place inside the brain. The bones and stones of paleoanthropology will acquire new meaning. The concept of human evolution and the family tree will dissolve into a process of capturing the particulate principle and equal-and-opposite. And our vision of ourselves as children of natural selection will dissolve into the inevitability of physics.

Our place in nature

Animals live in a world of biology, and interpret their experience as processes in biology, driven by natural selection. No dog possessing a sense of geometry and physics would chase and bite the tires of a moving bicycle –*tire-biters*– or a running vacuum-sweeper as if it were a living animal. And no gorilla possessing a sense of geometry and physics would recoil from a moving rope as if it were a living snake. When a dog hears, say, a fire-truck, it doesn't think *fire-truck*, or a chimney-brush, it does't think, *chimney-brush* –things that have nothing to do with the dog's evolutionary history. The dog thinks *Tyrannosaurus rex*, or some other kind of biological monster. Only human beings interpret their experience as events in geometry and physics, driven, originally, by the equal-and-opposite balance-scale that generates equations.

In 50 BC it was possible to believe that people, or at least a few of them, were derived entirely from the gods –and Caesar claimed descent from the goddess Venus. A century and a half later, Epictetus (page 108) demoted us by half, proclaiming our "body in common with the animals, and reason and intelligence in common with the gods". Epictetus's view prevailed until 1859, when Darwin (p. 488) relegated us entirely to the animals. Now we are none of the above. Our mind is generated in physics under the particulate principle, and by *equal and opposite* and its fractal duplications. Even our body, with the proportional arrangement on its naked skin, of pubic hair, navel, breasts and nipples, lips, eyes and hair, is a work of aesthetic art –imagined in the geometry of beauty, and asserted through sexual selection.

By showing that formative structures and properties of language represent orderly proliferations and ramifications generated under two laws in physics –the necessity of discreteness (for speech), and *equal and opposite* (for sentences)– the kluge hypothesis is disproved. It is thus no longer meaningful to imagine language as being assembled from precursors or antecedents out-of-order or out-of-context. For example lateralization, by itself, is not a precursor to language, and its isolated discovery in some other animal is not an indication that the components of language are widespread in the animal kingdom, and were somehow assembled by our early ancestors.

Human lateralization results from the introduction of the asymmetrical Subject-Object relationship to the archaic, symmetrical *N-V-N* sentence as a component of language. And it is also meaningless to suppose that under different conditions, some other system of language and mind might have emerged. The particulate principle and *equal and opposite* are universal laws of nature which apply under all conditions, and are not subject to

circumstances. The periodic property of the speech-sounds is a consequence of the physics of discreteness. Even the human sense of truth-and-falsity is generated by the same mechanism that generates sentences and assertions. The ability of animals to detect deception is thus not an indication that human logic is widespread in the animal kingdom, and somehow incorporated by early humans. Universal in language is not the same as basic or original.

A human being is a living thing that possesses the coordinated system of language and mind, generated in physics, as understood here. Language and mind are not generated in the complex interaction between synapses, neurotransmitters, excitatory, inhibitory, cholinergic, adrenergic, axons, nuclei and fiber tracts of the brain. Their organization represents the accommodation of an already-existing brain to the emerging consequences of the particulate principle and *equal and opposite*.

The concept of an origin (that is to say, the origin of language and mind) in physics provides a buffer of stability against the unregulated and even capricious nature of natural selection, whose results might vary widely depending on local conditions. Under the theory in physics, a few more zebras and a few less hippopotami in the environment would have made no difference in the structure of language. The concept of psychology will have to be re-thought, as all of human behavior is filtered through the structured stability of discreteness and equal-and-opposite.

Language-like behavior, sometimes reported in non-human primates, does not represent a little-changed continuation of the ancestor of language, or the beginnings of a new evolution of language in the modern day. It is just possible that natural selection brought structured behavior to an upper limit, crossing a threshold at which the latent mechanism in physics was activated, and assumed control.

The question that is asked, *How did language evolve?* conceals so many assumptions that it is unsafe. The first is that we know what language exactly is. While we might tell ourselves that we know (recognize) language when we see it, that is not the same as having an explicit theory of what language is. And when we don't know what a thing is, the question of its evolution is moot. Further, a demonstration of the power of natural selection is not a demonstration that natural selection had something to do with the origin of language. Such relationships must be shown on a case-by-case basis.

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References

Abler, B. (1973). *The Sensuous Gadgeteer* (later Shop Tactics). Philadelphia: Running Press. 114 .

Abler, W. L. (1989). On the particulate principle of self-diversifying systems. Journal of *Social and Biological Structures, 12*(1), 1-13.
Abler, W. L. (2005). *Structure of Matter, Structure of Mind. Sofia:* Pensoft; Philadelphia: BainBridgeBooks. xii+221.
Abler, W. L. (2010). The human mind: origin in geometry. *Science Progress, 93*(4),403-427.
Abler, W. L. (2013). On isolating, identifying and defining the uniquely human component of mind. *Cognitive Critique UMN, 7*,49-69. http://www.cogcrit.umn.edu/docs/abler2_v7.pdf
Abler, W. L. (2015). The design of the human being. *Cognitive Critique UMN, 8*,23-35. www.cogcrit.umn.edu/docs/abler_v8.pdf.
Beadle, G. and Beadle, M. (1966). *The Language of Life*. New York: Doubleday. xi+242 .
Boyer, C. & Merzbach, U. C. (1991). *A History of Mathematics*. Second edition. New York: John Wiley. xx+715.
Chomsky, N. (1957). Syntactic Structures. *The Hague: Mouton*. 116 pages.
Chomsky, N. (1965). *Aspects of the Theory of Syntax.* Cambridge: M.I.T. Press. x+251 .
Crosby, E. C., Humphrey, T. & Lauer, E. W. (1962). *Correlative Anatomy of the Nervous System.* New York: Macmillan. x+731.
Darwin, C. (1859). On the Origin of Species. London: John Murray. ix+490 pages.
Einstein, A. (1922). (G.B. Jeffery & W. Perrett, translators). *Sidelights on Relativity.* London: Methuen. 56.
Epictetus (AD 2nd c.). The Discourses. pages 99-245. In Robert Maynard Hutchins, editor 1952. Chicago: *Encyclopedia Britannica Great Books of the Western World*. volume 12, 310.
Everett, D.L. (2005). Cultural constraints on grammar and cognition in Pirahá Another look at the design features of human language. *Current Anthropology, 46*(4), 621-646.
Fisher, R. A. (1930). *The Genetical Theory of Natural Selection*. Oxford: The Clarendon Press. 272. Second revised edition, 1958. New York: Dover. xiv+291.
Gillespie-Lynch, K. (2017). Gestural theory of language evolution. in: Shackelford, Todd & Weekes-Shakelford, Viviana (2019). In *The Encyclopedia of Evolutionary Psychological Science*. Springer.
Harris, Z. S. (1951). *Methods in Structural Linguistics*. Chicago: The University of Chicago Press. xv+384.
Hauser, M. D., Chomsky, N. & Fitch, W. T. (2002). The faculty of language: what is it, who has it, and how did it evolve? *Science*, *298*(5598), 1569-1579.
Hersh, R. (1997). *What is Mathematics, Really?* New York: Oxford University Press. xxiv + 343.
Hewes, G., Andrew, R. J., Carlini, L., Hackeny, C., Gardner. R.A., Kortlandt, A., Krantz, G.S., McBride, G., Nottebohm, F., Pfeiffer, J., Rumbaugh, D.G., Steklis, H.D., Raliegh, M. J., Stopa, R., Suzuki, A., Washburn, S. L. & Wescott, R.W. (1973). Primate communication and the gestural origin of language. *Current Anthropology*, *14*(1-2), 5-24.
Hockett, C. F. (1960). The origin of speech. *Scientific American*, *203*(3), 88-111.
Hockett, C. F. (1963). *The problem of universals in language*. pp. 1-22 in Greenberg, J. H. (ed) 1963. Universals of Language. Cambridge: MIT Press. x+269.
Hyman, L. M. (ed.) (1973). *Consonant Types & Tone*. Los Angeles: Southern California

Occasional Papers in Linguistics SCOPIL no. 1. vii+179 pages.
IPA (1949). *The Principles of the International Phonetic Association.* London: International Phonetic Association, Department of Phonetics, University College. 53 pages.
Jakobson, R. (1970). Linguistics. pages 419-463 in: UNESCO 1970. *Main Trends of Research in the Social and Human Sciences, Part one: Social Sciences*. Paris: Mouton. XLVII+ 819 pages.
Jensen, W. B. (ed.) (2005). *Mendeleev on the Periodic Law.* Mineola: Dover. 314 pages.
Lakoff, G. & Núñez, R. (2000). *Where Mathematics Comes From.* New York: Basic Books. XVII+ 492 pages.
Langendoen, D. T. (1969). *The Study of Syntax.* New York: Holt, Rinehart and Winston. 174 pages.
Liberman, A., Cooper, F. S., Shankweiler, D., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review, 74*(6). 431-461.
Mandelbrot, B. (1983). *The Fractal Geometry of Nature*. New York: W.H. Freeman. 468.
Marcus, G. (2008). *Kluge. Boston:* Houghton Mifflin. 211.
McNeill, D. (2002). Gesture and language dialectic. *Acta Linguistica Hafniensia,* 34(1) 7-37.
Mendeleev, D. (1868-1870) (in Russian), (1901). *The Principles of Chemistry. A Library of Universal Literature*. St Louis Publishing Company. 4 volumes.
Nordström, J. (2014). Language as a discrete combinatorial system, rather than a recursive-embedding one. *The Linguistic Review, 31*(1), 151-191.
Nowak, M. A., Plotkin, J. B. & Jansen, V. A. A. (2000). The evolution of syntactic communication. *Nature*, *404*(6777), 495-498.
Nowak, M. A., Komarova, N. L. & Niyogi, P. (2001). Evolution of universal grammar. *Science*, *291*(5501), 114-118.
Opie, I. & Opie, P. (1959). *The Lore and Language of Schoolchildren*. Oxford: The Oxford University Press. xviii+417 pages.
Pinker, S. & Bloom, P. (1990). Natural language and natural selection. Behavioral and Brain Sciences, *13*(4), 707-784.
Pinker, S. (1994). *The Language Instinct*. New York: William Morrow. 494 pages.
Robins, G. & Shute, C. (1987). *The Rhind Mathematical Papyrus*. New York: Dover. 59 pages + 24 plates.
Schrödinger, E. (1946). *What is life?* New York: Macmillan viii+91 pages.
Sommer, A. P. et al. (2008). Crystalline water at room temperature -under water and in air. *Crystal Growth & Design, 8*(8), 2620-2622.
Tegmark, M. (2014). *Our Mathematical Universe*. New York: Alfred A. Knopf. viii+421.
Thackray, A. (1972). *John Dalton.* Cambridge: Harvard. xiv+190 pages.
Verhoef, T., Kirby, S. & de Boer, B. (2015). Iconicity and the emergence of combinatorial structure in language. *Cognitive Science, 40*(8), 1969-1994.
Wigner, E. P. (1960). The unreasonable effectiveness of mathematics in the natural sciences. *Communications on Pure and Applied Mathematics, 13*(1), 1-14.

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