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Realising the Enlightenment: H.T. Odum's Energy Systems Language *qua* G.W.v Leibniz's *Characteristica Universalis*

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Abstract

Gottfried Wilhelm von Leibniz (1646–1716) is usually regarded as one of the world's greatest philosophers. If our thesis is right—that the Energy Systems Language is a *Characteristica Universalis*—the late Howard Thomas Odum (1924–2001) shares in this title. Moreover the work of H.T. Odum and colleagues can be considered a progression of natural science, creatively realising what contemporary German philosopher J. Habermas calls the project of the Enlightenment. As a consequence, H.T. Odum's work is worthy of far greater historical profundity and philosophical respect than many may have previously imagined.

Keywords: Enlightenment; Profundity; Energy Systems Language; Characteristica Universalis

> There has been for many years a crisis in Philosophy. Philosophy once claimed to be the most general of intellectual fields but lost that intellectual leadership of pure ideas, perhaps because its practitioners did not become quantitative or test their concepts against quantitative evaluations of the real world. General systems theories are a way of reuniting the fields that seek to generalize knowledge.[1]

1. Introduction

This essay will explore the relation between H.T. Odum's Energy Systems Language and G.W.v Leibniz's unfinished philosophical language project, the *Characteristica Universalis* (Latin: Universal Characteristic). In particular, we will assess the degree to which Energy Systems Language qualifies as an example of the philosophical language envisioned by Leibniz. G.W.v Leibniz's was a 16th century German Enlightenment philosopher who advanced the *Characteristica Universalis*: a planned, though vaguely sketched, philosophical language that would be 'fixed in the nature of things' for the synthesis of human knowledge. The Energy Systems Language, developed by H.T. Odum (founder of systems ecology), is a set of 15 or so symbols, as well as a series of rules for their connection (or syntax). It is primarily used for the description of ecological systems and by extension to any other system that can be predicated on the principles of ecological energetics. Even this brief sketch of these two symbolic projects demonstrates that their resemblance warrants further investigation. To that end, we will first identify the aims and approaches shared by H.T. Odum and Leibniz, and locate both within the Enlightenment movement.

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[1] Odum, H.T., 1995. Energy Systems and the unification of science. In: Hall, C.S. (Ed.), Maximum Power: The Ideas and Applications of H.T. Odum. Colorado University Press, Boulder CO, p. 368.

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Second, we will demonstrate Leibniz's contribution to much of the material systematised by H.T. Odum's Energy Systems Language. Third, we will present a brief history of the *Characteristica Universalis* and identify its distinguishing features. We conclude that the Energy Systems Language does in fact share these distinguishing features, qualifying it as a significant contribution to the unfinished Enlightenment project.

2. Leibniz and the enlightenment

2.1. Shared aims and approaches of H.T. Odum and G.W.v Leibniz

In order to better appreciate the significance of the Energy Systems Language (and its architect, H.T. Odum) we begin by locating its aims and approaches in the continuing context of the history of ideas from which it has arisen. To this end, we further identify the broader philosophical movement, namely 'the Enlightenment', to which it belongs. In particular, H.T. Odum's work is related to the central exponent of this movement, G.W.v Leibniz. Leibniz's work stands as a signpost along the path of Enlightenment history.

In the "*Preface to the First Edition*" of his "*Ecological and General Systems: An Introduction to Systems Ecology*" (the seminal text that formalised the Energy Systems Language), H.T. Odum began as follows:

> If the bewildering complexity of human knowledge developed in the twentieth century is to be retained and well used, unifying concepts are needed to consolidate the understanding of systems of many kinds and to simplify the teaching of general principles.[2]

Here, the central aim and recommended approach we seek to emphasise, are presented explicitly and succinctly. The aim is to retain and use the complexity of human knowledge. The approach is to unify a multiplicity of systems principles. If these aims are broadened beyond the twentieth century, then H.T. Odum can be seen to share Leibniz's fervour for the Enlightenment vision. In his "*Of Universal Synthesis and Analysis*" Leibniz laments at what critical theorists, M. Horkheimer and T.W. Adorno later identified as the Enlightenment's capacity for, 'indefatigable self-destructiveness':[3]

> . . . one must marvel at the carelessness of men, wasting their time on trifles and neglecting those things by which they might provide for their health and well-being, when they might perhaps have in their power the remedies for a great part of their ills if they would use rightly the copious observations of this century which are already available, and also the true analysis. But as things are, man's knowledge of nature seems to me like a shop, well stocked with goods of all kinds, but lacking any order or inventory.[4]

We find here Leibniz's central aim and recommended approach to be in striking resemblance to those of H.T. Odum. Leibniz's aim is to "use rightly copious observations" for the "well-being" of humankind. His approach is to use "the true analysis" to order "man's knowledge of nature". These are next discussed in terms of two characteristic concepts of the Enlightenment; the aim of a *Philosophia Perennis* and the approach of *Unitas Multiplex*.

2.2. The Aim: philosophia perennis

Regarding Leibniz's aims, both L. Loemker and A. Huxley identified the 16th century German philosopher as the main instigator of *philosophia perennis* (Latin: 'perennial philosophy').[5] Huxley described this as a general system of metaphysics that is immemorial and universal and so can be found in the "traditionary lore" of peoples in every region of the world.[6] Loemker has characterised the aim of *philosophia perennis* as ". . . the synthesis of what

[2] Odum, H.T., 1994. Ecological and General Systems: An Introduction to Systems Ecology. University Press of Colorado, Niwot, CO.

[3] Horkheimer, M., Adorno, T.W., 1969. Dialectic of Enlightenment. Herder and Herder, New York, pp. xi, xii.

[4] Leibniz, 1974. Of universal synthesis and analysis. In: Parkinson, G.H.R. (Ed.), Leibniz: Philosophical Writings, 2nd ed., p. 16.

[5] It should be noted that the term, '*philosophia perennis*' is derived from the title of an earlier work by Agostino Steuco of Gubbio in 1540. McInterny, R., 1999. Philosophia perennis. In: Audi, R. (Ed.), The Cambridge Dictionary of Philosophy, 2nd ed. Cambridge University Press, p. 667.

[6] Huxley, A., 1958. The Perennial Philosophy. Fontana Books, London, p. 9.

is good in all systems".[7] Here, differences between philosophers are largely superficial and a common truth emerges when the various schools of thought are unified.[8] As will be discussed below, Leibniz had intended that such unification would be achieved through the development of a *lingua philosophia*[9] (Latin: Philosophical Language). In Leibniz's day, it was the competing metaphysical assumptions (regarding the fundamental nature of existence) within philosophy that provided much of the variety among the schools of thought that Leibniz sought to systematise. Despite Leibniz's efforts, Immanuel Kant found that metaphysics had "lapsed back into the ancient time-worn dogmatism".[10] Indeed today many of these differing metaphysical assumptions have become embodied in the various sub-disciplines of science. Much of what was 16th century 'philosophy' would now be regarded as 20th century 'science'. As such, it is the perplexity of specialisations in the sciences that would be subject to selective integration into *philosophia perennis*. Even a few of the broad disciplines that H.T. Odum incorporated into the Energy Systems Language demonstrate this, including; thermodynamics, energetics, ecology, economics, cybernetics, and, political science. In his own words, H.T. Odum testified to this general aim: "... more of our students should participate in groups that attempt to unify science ... ".[11]

While Leibniz did not achieve this synthesis of human knowledge in his own time, it is instructive to note the breadth of his influence on such a variety of schools of thought as he wished to encompass with the *philosophia perennis*. As a principal case in point, Leibniz's influence on Enlightenment thinking has been both deep and wide. E. Cassirer has asserted that Leibniz's treatise *On Wisdom* "... identified the central concept of the Enlightenment and sketched its theoretical program".[12] In fact, much of the growth of German philosophical and scientific thought was guided by Leibniz's Enlightenment vision.[13] With regard to the aims of this Enlightenment movement, the contemporary German philosopher J. Habermas has commented:

> The Enlightenment philosophers wanted to utilize [the] accumulation of specialized culture for the enrichment of everyday life, that is to say, for the rational organization of everyday social life.[14]

Furthermore, Leibniz's considerable influence has not been limited to his country of origin. For example, through the work of Maupertuis, Leibniz influenced much of French philosophy.[15] So much so, that the 18th century French Enlightenment Philosophers, Diderot and Fontenelle, agreed that: "Germany has gained as much honour through this one mind as Greece did through Plato, Aristotle, and Archimedes together".[16] Indeed, the eminent American philosopher John Dewey regarded Leibniz as the greatest intellectual genius since Aristotle.[17] These commendations, along with those to be discussed in relation to the natural, social and life sciences, would seem to qualify Leibniz as an eminent contributor to the *philosophia perennis*. His legacy is clearly of central importance to the continuing history of those endeavours, such as H.T. Odum's, that aim to systematise "man's knowledge of nature". For H.T. Odum, this was what he wanted for his students: "... my teaching objectives were always to train general theorists with environmental science as the practical realm of application".[18]

7 Loemker (Ed.), 1976. Gottfried Wilhelm Leibniz: Philosophical Papers and Letters, vol. 2. Synthese Historical Library, D. Reidel Publishing Company, Dordrecht-Holland, p. 9.

8 McInterny, R., 1999. Philosophia perennis. In: Audi, R. (Ed.), The Cambridge Dictionary of Philosophy, 2nd ed. Cambridge University Press, p. 667.

9 See Rutherford, D., 1998. Philosophy and language in Leibniz. In: Jolley, N. (Ed.), The Cambridge Companion to Leibniz. Cambridge University Press, p. 249.

10 Kant, I., 1933. Immanuel Kant's Critique of Pure Reason. Macmillan, London, p. 8.

11 Odum, H.T., 1995. p. 365.

12 Cassirer, E., 1979. The Philosophy of Enlightenment. Princeton University Press, pp. 121–123.

13 Ibid, p. 81.

14 Habermas, J., 1981. Modernity versus Post Modernity. New German Critique, Holland, vol. 22, p. 9.

15 Cassirer, E., 1979. p. 86.

16 Ibid, p. 35.

17 Westbrook, R.B., 1992. John Dewey and American Democracy. Cornell University Press, p. 21. Dewey's reverence for Leibniz deserves special significance, since he promised to write up his "famous course on social philosophy" for, "Howard Odum". See Randall Jr., J.H., 1953. John Dewey: 1850–1952. In: Besser, S.M. (Ed.), Dewey and His Critics. J. Philos. (U.S.A.) 5.

18 Odum, H.T., 1995. p. 367.

2.3. The approach: unitas multiplex

As indicated above, H.T. Odum seems to have shared his general approach with Leibniz, and by implication, the Enlightenment movement. For Cassirer,[19] Enlightenment science and systematic philosophy have always found their way back to the fundamental question of *unitas multiplex*[20] (Latin: 'unity in multiplicity'). This concept is recognizable in both the history of the Energy concept, with R.B. Lindsay's phrase, "constancy in the midst of change"[21] and in the ecological approach to perception, with J.J. Gibson's notion of "invariants under transformation".[22] For Horkheimer and Adorno, the Enlightenment conceives the existence of things by their unity: "its ideal is the system from which all and everything follows".[23] This was a foundation for Leibniz's Enlightenment approach. As C.S. Hall recognises, the philosophy of *unitas multiplex* is "essentially the basis for systems thinking of the sort that H.T. Odum brought to full fruition".[24] In his *General Systems Theory*, L.v Bertalanffy agrees: "As 'natural philosophy' we may trace [the systems concept] back to Leibniz".[25] For Cassirer, this *esprit systématique* (French: systematic spirit) is what the philosophy of the Enlightenment aims to further.[26] Of this perspective, Cassirer writes:

> Philosophy is no special field of knowledge situated beside or above the principles of natural science, of law and government, etc., but rather the all-comprehensive medium in which such principles are formulated, developed and founded.[27]

The significant change in thinking embodied in Enlightenment thought was the transformation of fixed and finished philosophical concepts into active forces.[28] The approach of *unitas multiplex* brings order or inventory to the well-stocked shop and thus unifies the complex of human knowledge of nature. It further ensures that such a unification is in a form that will be useful in providing for the "well-being" of human kind. Correspondingly, H.T. Odum's Energy Systems Language is both an approach for ordering a wealth of scientific understanding as well as an implement for the "design of human society with its natural environment for the benefit of both".[29] Such an approach is consistent with what Habermas identifies as the Enlightenment goal of "reason forming itself into reality".[30]

3. Leibniz and ecological energetics

3.1. Leibniz and classical science

The importance of Leibniz to the Energy Systems Language is not limited to their shared aims and approaches. Leibniz's work in Physics generally has also largely furnished the raw materials for H.T. Odum's synthesis. A surprising proportion of "the bewildering complexity of human knowledge developed in the twentieth century", was actually contributed, directly or indirectly, by G.W. Leibniz in the 16th century.[31] The era of the rise of classical science is often referred to as 'Cartesian-Newtonian', emphasising the influence of these thinkers on the development of the 'mechanistic conception' of the world and life.[32] As suggested above, this is done to the neglect of the legacy of Leibniz's contribution to the sciences. For example, as Magee points out: Leibniz "... invented calculus not knowing that Newton had already done

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[19] Cassirer, E., 1979. pp. 121–123.
[20] Angyal, A., 1941. A logic of systems. In: Emery (Ed.) (1978), Systems Thinking. Penguin Modern Management Readings, UK, p. 28.
[21] Lindsay, R.B., 1975. Energy: Historical Development of the Concept. Benchmark Papers of Energy, vol. 1. Hutchinson & Ross, Inc., Dowden, USA, p. 5.
[22] Gibson, J.J., 1979. The Ecological Approach to Visual Perception. Lawrence Erlbaum, Hillsdale, NJ.
[23] Horkheimer, Adorno, 1969. p. 7.
[24] Hall, C.S., 2003. Personal communication.
[25] Bertalanffy, L.v., 1968. General SYSTEM THEORY: Foundations, Development, Applications. George Braziller, New York, p. 11.
[26] Cassirer, E., 1979. p. vii.
[27] Ibid.
[28] Ibid.
[29] Mitsch, W.J., Jorgensen, S.E., 1989. Ecological Engineering: An Introduction to Ecotechnology. Wiley, New York, p. ix.
[30] Habermas, J., 2001. Conceptions of modernity: a look back at two traditions. In: Pensky, M. (Ed.), The Postnational Constellation: Political Essays. Polity Press, Cambridge, p. 136.
[31] This point is also made by Lindsay (1975) p. 109.
[32] Capra, F., 1982. The Turning Point: Science, Society and the Rising Culture, 2nd ed. Harper Collins Publishers, London.

so, and he published it before Newton did: in fact it is his notation, not Newton's, that we use to this day".[33]

There may be good reason, however, for maintaining a distinction between the more reductionist approaches of Descartes and Newton and the more systemic approach of Leibniz. Cassirer[34] insists that neither the Cartesian notion of 'extension' nor the Newtonian notion of 'gravity' assist in understanding the phenomena of life. Generally, the metaphysics of 'extension' is understood as substance. That is, as the essence of that which occupies physical space and exists in time, that which is tangible, can be divided, has shape or figure and is capable of being changed and moved.[35] Aggasi emphasises that for Descartes matter is pure extension. In contrast, for Leibniz matter is both extension *and* force, where 'matter' and *not* 'space', is substantial. That is, according to Aggasi, "[e]xtension ... is the order of relations among points endowed with force".[36]

This metaphysical attitude appears strangely out of place in the 16th century and would seem more at home with the field theories and systems thinking of the 20th century. Indeed this characteristically modern approach to scientific thought furnished the conditions for the development of Cybernetics. N. Weiner, its founder, defines Cybernetics as the study of "Control and Communication in the Animal and the Machine",[37] and has dubbed Leibniz "the patron saint for Cybernetics".[38] W.R. Ashby has characterised 'cybernetic systems' as 'self-correcting' and involving 'negative feedback', in which "the error is fed back into the mechanism to cause its own reduction".[39] Moreover as a 'mining engineer',[40] Leibniz constructed just such a system, in the form of a feedback controlled speed regulator designed to maximize the power of windmills used in silver mining.[41] These developments have in turn been central to the development of the ecosystem concept.[42] As B.C. Patten and E.P. Odum (H.T. Odum's brother) have argued, "ecosystems are cybernetic" systems.[43] H.T. Odum, the 'father' of systems ecology,[44] has also recognised the value of understanding the cybernetics of ecological systems.[45] By implication, we tender Leibniz as the 'patron saint' of systems ecology.

3.2. Leibniz and mathematical physical biology (Systems Ecology)

Leibniz stressed the doctrine that life be formulated in a way that did not contradict the basic principles of mathematical physics, or *Philosophiae naturalis principia mathematica*[46] (Latin: Mathematical Principles of Natural Philosophy). In contrast to the Cartesian-Newtonian approach, where space is conceived as an essentially abiotic substance, Leibnizian space is a system of relations of order among things: "Space and time ... are the relations of order, viz. of coexistence and succession among phenomena and qualities".[47] Cassirer wrote that in this system of relations the harmony between thinking biologically and physically "... can only be assured if one realizes that all the phenomena of nature, without exception, are capable of a strictly mathematical and mechanical explanation".[48]

A.J. Lotka conceived such an approach in his *Mathematical Biology*: "The rate of formation (growth) ... will ... depend largely upon the *mechanical* properties of those portions of the system which ac-

[33] Magee, B., 1988. The Great Philosophers: An Introduction to Western Philosophy. Oxford University Press, Oxford, p. 99.

[34] Cassirer, E., 1979. p. 87.

[35] Angeles, P.A., 1981. Dictionary of Philosophy. Harper and Row, New York, p. 91.

[36] J. Agassi identifies this 'Leinbnizian kernel' as the kernel of Einstein's relativity theory of space. Agassi, J., 1969. Leibniz's place in the history of physics. J. Hist. Ideas 30 (3), 333.

[37] Weiner, N., 1948. Cybernetics: Or Control and Communication in the Animal and the Machine. Wiley, New York.

[38] Ibid, p. 20.

[39] Ashby, W.R., 1949. Critical review: the facts and methods of cybernetics. J. Ment. Sci. 95, 717.

[40] The term is Mirowski's. Mirowski, P., 1999. More Heat than Light: Economics as Social Physics, Physics as Nature's Economics. Cambridge University Press, Cambridge, p. 122.

[41] Munzenmayer, cited in Aiton, E.J., 1985. Leibniz: A Biography. Adam Hilger, Bristol/Boston, p. 111.

[42] Hutchinson, G.E., 1948. Circular causal systems in ecology. Teleological mechanisms. Ann. N.Y. Acad. Sci. 50 (4), 214.

[43] Pattern, B.C., Odum, E.P., 1981. The cybernetic nature of ecosystems. Am. Nat. 188, 886–895.

[44] See inside front dustcover in Odum, H.T., 1996. Environmental Accounting: Emergy and Environmental Decision Making. Wiley, New York.

[45] Odum, H.T., 1994. Ecological and General Systems, p. 72.

[46] Agassi, J., 1969. p. 331. See also Cassirer, E., 1979. p. 82; and Cassirer, E., 1942. p. 312.

[47] Agassi, J., 1969. pp. 331–332.

[48] Cassirer, E., 1979. pp. 82–83.

company this ... complex in its travels ... ".[49] S.E. Kingsland notes that Lotka's view was based on the proposition that, "transfers of matter involve the transfers of energy",[50] and that, "[t]hese two types of transfer were really aspects of the same thing".[51] This again resonates with Leibniz's metaphysics of 'substance', described above. Indeed energeticist W. Ostwald stressed that genuine energetics should treat energy as a real substance, not just a mathematical abstraction.[52] Following Ostwald, Lotka, Bertalanffy and many others, H.T. Odum subsequently produced the Energy Systems Language as a synthetic universal network language for Systems Ecology.[53] Regarding this H.T. Odum wrote: "... mathematics and physical laws need not be separated if languages for their expression synthesise both these disciplines".[54] Importantly, it was energetics and the unifying principles of 'energy transformation and flow' that afforded H.T. Odum such a synthesis. As will be demonstrated below, 'energy' was also a central concern for Leibniz.

3.3. Leibniz and energetics

As with many fields of inquiry, Leibniz's exploration of energetics was substantial and comprehensive. In the 1880s energeticist G. Helm recognised that Leibniz had argued for the impossibility of perpetual motion and that this argument "later made the foundation of the energy law by Helmholtz".[55] Einstein apparently professed himself to be a Leibnizian[56] and recognised Leibniz as responsible for advancing the principle of energy conservation.[57] M. Jammer considered Leibniz to be one of the first modern relativists in his rejection of Newton's theory of absolute space, on the grounds that "space is nothing but a network of relations among co-existing things".[58] P.M. Heimann documents parallels between Leibniz's statements of the equality of cause-and-effect and the principle of causality as established by the seminal[59] energeticist J.R. Mayer.[60] Moreover, N. Weiner postulated the view of Leibniz's philosophy as "... a basis for Quantum Mechanics".[61] Both Agassi and Weiner claimed that Leibniz's ideas were partly responsible for the development of field theory in physics.[62] Furthermore, according to Magee, it was Leibniz that first "... coined the notion of kinetic energy".[63] Boltzmann contended that in the many passages where Leibniz refers to the 'substantiality of force' he meant by this 'energy'.[64] From Leibniz onwards, says Boltzmann, the energy concept "... gradually grew into a mighty bond encompassing the whole world of phenomena",[65] thus furnishing the possibility of an energetic understanding of phenomena that have 'quality'.

Boltzmann also emphasised that Leibniz did not have a notion that heat was a form of energy.[66] Without this notion, it is apparent why Leibniz may have lost faith in his plan for a philosophical language—his *Characteristica Universalis*. That is, Leibniz could not use energy transformed into heat as a basis upon which to unify and predicate the symbols of his philosophical language. Nevertheless in Leibniz's writings

[49] Lotka, A.J., 1957. Elements of Mathematical Biology. Dover Publications, New York, p. 14.
[50] Kingsland, S.E., 1985. Modeling Nature. University of Chicago Press, Chicago, p. 34.
[51] Ibid.
[52] W. Ostwald in Deltete, R.J., 1997. The Energetics Controversy in Late Nineteenth-Century Germany: Helm Ostwald and Their Critics, vols. I and II. Ph.D. Thesis, Authorised Facsimile, vol. I, UMI Dissertation Service, A Bell & Howell Company, Michigan, p. 135.
[53] Odum, H.T., 1994. Ecological and General Systems: An Introduction to Systems Ecology. Colorado University Press, Colorado, pp. 4, 6.
[54] Ibid, p. 4.
[55] Helm in Deltete, 1997. II, ft. 2–8, 702–703.
[56] Agassi, J., 1969. p. 331. Einstein says that Leibniz-Huygens space was intuitively well-founded and justified, A. Einstein in Jammer, M., 1960. Concepts of Space: The History of the Theories of Space in Physics. Harper & Brothers, New York, p. xv.
[57] Einstein, A., 1957. $E = MC^2$. In: Great Essays in Science. Pocket Books, New York, p. 404.
[58] Jammer, M., 1960. Concepts of Space. pp. 2, 48.
[59] Deltete, 1997. Vol. II, ft. 3–4, p. 703.
[60] Heimann, P.M., 1976. Mayer's Concept of "Force". In: McCormmach, R. (Ed.), Historical Studies in the Physical Sciences. Seventh Annual Volume. Princeton University Press, New Jersey, p. 287.
[61] Weiner, N., 1934. Quantum Mechanics, Haldane, and Leibniz. Philos. Sci. 1 (4), 479.
[62] Agassi, J., 1969. p. 331. Weiner, N., 1934. p. 482.
[63] Magee, B., 1988. p. 99.
[64] Boltzmann, 1974. Theoretical Physics and Philosophical Problems. D. Reidel Publishing Company, Holland, p. 91.
[65] Ibid, p. 144. Helm shares this, "view of nature encompassing all experience". Helm in Deltete, 1997. Vol. I, p. 127.
[66] Boltzmann, 1974. p. 144.

we may find evidence of nascent sketches of the second and fourth energy principles regarding 'entropy' and 'maximum power efficiency', respectively.[67] These principles, which culminated in Lotka's energetics of evolution,[68] are of fundamental importance to H.T. Odum's approach[69] and receive considerable treatment in his "*Ecological and General Systems*". Here, H.T. Odum defines energy quantitatively as the heat released in an energy transformation.[70] Thus giving heat generation a central role in unifying and predicating the symbols of the Energy Systems Language. This is the very role that was lacking in Leibniz's attempt at a philosophical language.

Given this striking connection, the remainder of this essay will focus on the relation between G.W. Leibniz's philosophically obscure *Characteristica Universalis* and H.T. Odum's Energy Systems Language. Despite its obscurity, many philosophers understand the *Characteristica Universalis* as the most significant and central aspect of Leibniz's philosophy;[71] an aspect around which much of his other physical and metaphysical thinking revolved. In particular, we will now explore Leibniz's *Characteristica Universalis* project, which aimed to develop symbols for a philosophical language that synthesised mathematical and physical laws. We will be concerned here with the degree to which H.T. Odum's Energy Systems Language can be recognised as a modern form of this project.

4. The history of the *Characteristica Universalis*

4.1. Scepticism, neglect and insufficient progress

Given the impressive contribution of Leibniz to the development of the unfinished project of the Enlightenment, one may be forgiven for wondering why the project remains unfinished. One reason is that the realisation of the Enlightenment project would seem to involve the creation of a universal philosophical language, or *Characteristica Universalis*. Alternatively, as explored below, the task might simply be one of adopting a Hegelian approach by looking among the various banks of literature to recognise a modern form of the *Characteristica Universalis*.[72] Consequently, we will now consider various obstacles that have stood in the path of both of these alternatives—the deliberate development of the *Characteristica Universalis* and the seeking out of existing examples of it.

As suggested above Leibniz's continuing legacy is of considerable relevance to contemporary philosophy. In particular, Rutherford regards the *Characteristica Universalis* as the core of Leibniz's understanding of language.[73] However, both philosophers and historians of philosophy have relegated *Characteristica Universalis*-type projects to the scientific revolution of the 16th and 17th centuries indicating an anomalous neglect for this aspect of Leibniz's philosophy. The sentiment of Parkinson's comments is commonplace, especially among analytical philosophers who currently dominate the profession:

> Leibniz's views about the systematic character of all knowledge are linked with his plans for a universal symbolism, a *Characteristica Universalis*. This was to be a calculus which would cover all thought, and replace controversy by calculation. The ideal now seems absurdly optimistic. . . .[74]

C.J. Cohen says that philosophical language projects of the *Characteristica Universalis*-type were not unusual in the seventeenth century.[75] Unfortu-

[67] This point requires further attention and will be the subject of a forthcoming publication, but see: Leibniz, 1686. A brief demonstration of a notable error of Descartes and others concerning a natural law.

[68] Lotka, A.J., 1922. Contribution to the energetics of evolution. Proc. Natl. Acad. Sci. U.S.A. 148.

[69] Hall, C.S., 1995. Introduction: what is maximum power? In: Hall, C.S. (Ed.), Maximum Power: The Ideas and Applications of H.T. Odum. University Press of Colorado, Niwot, CO, pp. xiii–xv.

[70] Odum, H.T., 1994. p. 95.

[71] Rutherford, D., Philosophy and language in Leibniz. In: Jolley, N. (Ed.), The Cambridge Companion to Leibniz. Cambridge University Press, Cambridge, UK, p. 225.

[72] "Hegel", writes Habermas, "was well aware that the desired goal of reason forming itself into reality could only be proved with historical evidence". Habermas, J., 2001. Conceptions of modernity: a look back at two traditions. In: Pensky, M. (Ed.), The Postnational Constellation: Political Essays. Polity Press, Cambridge, p. 136.

[73] Rutherford, D., 1998. p. 225.

[74] Parkinson, G.H.R., 1988. Leibniz: Philosophical Writings. Everyman Press, p. ix. On the question of whether the *Characteristica* could ever be realised D. Rutherford (1998) says, 'arguably not'. p. 231.

[75] Cohen, C.J., 1954. On the project of a universal character. Mind (New Series) 63 (249), p. 60.

nately most such attempts did not try to unify knowledge but rather to categorize and label it. In describing the history of philosophical languages[76] and the 'universal language movement', M.M. Slaughter[77] reports that they were largely only "... attempts to create taxonomic nomenclatures. ...[P]roducts of what Michael Foucault has called a taxonomic episteme ..."[78] (Greek: Knowledge). This tendency has had significant implications for the development of ecological thought, as the pattern identified in Slaughter's characterisation of the history of universal languages has been replicated in the teaching of both ecology and environmental ethics. For example, both P. Hay and D. Pearce, have expressed the concern that environmental ethics suffers from an extreme form of "labilitis", (i.e., excessive adherence to labels) to the extent that postmodern ecology has tended to reject ecological wholism.[79] Equally M.T. Brown and C.S. Hall note to their dismay that ecology is presently taught principally using species-oriented approaches (i.e., taxonomic nomenclatures).[80]

We can recognise another parallel here in that Slaughter also explicitly excludes Leibniz's *Characteristica Universalis* project from her analysis, and that many ecologists rarely focus on or use the circuit diagrams of H.T. Odum's Energy Systems Language. This is noteworthy because the species-oriented, taxonomic approaches of both analytic ecology and analytic philosophy categorise phenomena by reducing them to their parts on the basis of their formal identities. In describing the use of analytical methods Leibniz nevertheless warns of its potential drawbacks if used in the absence of synthetic methods: "Analysis goes back to principles solely for the sake of a given problem, just as if nothing had been discovered previously, by ourselves or by others".[81] Horkheimer and Adorno contend that this reductionist tendency has in fact eventuated. They suggest that this ascendancy of analytical methods has been largely due to the increasing specialisation of the division of labour within capitalist social relations:[82] "thought becomes commodity and language the means of promoting that commodity".[83] Accordingly, we suggest that the analytical method flourishes within the specialised discourse of a given discipline because of the need to develop taxonomies of the vocabulary specific to a field of inquiry. This tendency discourages, and in fact hinders, communication between disciplines, which to a large extent may have already solved each others problems, though, couched in otherwise inaccessible terminology. The synthetic method, which requires a trans-disciplinary approach, suffers under the regime of specialised intellectual labour because it challenges established notions of intellectual capital. Thus, a synthetic philosophical language is anathema to analytic reasoning in all disciplines where the intellectual labour and language of inquiry are not generalized, but rather divided into specialist guilds. Such a consideration might explain some of the neglect of the Energy Systems Language and *Characteristica Universalis* in both analytic ecology and philosophy.

Despite these misgivings and commonplace cases of neglect for the *Characteristica Universalis*-type projects, they have survived. There have been a variety of attempts to maintain an active and positive, if somewhat inadequate, attitude towards their prospects. As Eschbach notes, those who envisaged the development of a *Characteristica Universalis* were mostly attached to pansophical (universal knowledge) and progressive scientific knowledge groups in London and Oxford (known as the 'Invisible College')—forerunners to the Royal Society.[84] Some lexicographers have surmised that J. Wilkins (one of the founders of the Royal Society) viewed the inception of his, and the first ever, thesaurus as "... a first step towards a universal language and a universal

[76] Like J. Wilkin's 'Essay Towards a Real Character and a Philosophical Language' for instance, which was supported by the young Royal Society. Dascal, M., 1987. Leibniz: Language, Signs and Thought, A Collection of Essays. John Benjamins Publishing Company, Amsterdam, p. 169.

[77] Ecological linguists might like to note that for Slaughter such languages, '... popped up like *weeds* during the seventeenth century' (our italics), and were meant to represent cosmic classifications. Slaughter, M.M., 1982. Universal Languages and Scientific Taxonomy in the Seventeenth Century. Cambridge University Press, Cambridge, New York, p. 1.

[78] Ibid., pp. vii, 2.

[79] D. Pearce in Hay, P., 2002. Main Currents in Western Environmental Thought. University of New South Wales Press, Sydney, p. 340.

[80] Brown, M.T., Hall, C.S., 2003. See preface of this publication.

[81] Leibniz in Parkinson (Ed.), 1988. p. 16.

[82] Horkeimer, Adorno, 1969. p. 35.

[83] Ibid., pp. xi, xii.

[84] Eschbach, 1984. Mercury: Or the Secret and Swift Messenger. John Benjamins Publishing Company, Amsterdam, p. xv, xix.

character".[85] Logician K. Gödel was a rare exception in his belief in the possibility of the concept. As M. Davis writes, "Gödel held out the hope that such a language could be developed and that it would revolutionize mathematical practice".[86] Indeed, M. Dascal[87] takes Leibniz's work on universal language, signs and thought as seminal for the foundations of semiotics.[88] More recently, Kusch, Hintikka and Shin present interesting discussions.[89] However, like Leibniz, they seem to lack a basis upon which to predicate the symbols of philosophical language. As suggested above, H.T. Odum's Energy Systems Language has such a basis and therefore deserves attention as a candidate for the *Characteristica Universalis*.

4.2. Leibniz on the Characteristica Universalis

Leibniz's writings on the *Characteristica Universalis* are scattered throughout his philosophical works. In some cases they receive only partial translation into English. In fact for Gödel the absence of the *Characteristica Universalis* in Leibniz's publications appeared systematic. So much so that Gödel seems to have believed in a conspiracy to suppress Leibniz's *Characteristica Universalis* project.[90] But due to the work of esteemed intellectuals, we have access to some texts appearing in, amongst other places, Leibniz's "Dissertation on the Art of Combinations", his "On the General Characteristic", and "Of Universal Analysis and Synthesis".[91]

Adding to the difficulty for our treatment is that Leibniz's terminology changes over the course of his life. Sometimes he talks of a *General Character*, other times of a symbolic language. For example, in a letter to Christian Huygens, Leibniz included a supplement in which he describes his discovery of a new characteristic, or symbolic language. In this supplement, Leibniz suggests that with this linguistic tool one could give exact descriptions of natural things "such, for example, as the structure of plants and animals".[92] It will be a general symbolic method "by means of which the relations of all things are suitably represented in characters".[93] "With its aid", remarked Leibniz:

> . . . people who find it hard to draw figures could explain a matter perfectly, provided they have it present before them or in their mind, and could transmit their thoughts and experiences to posterity—a thing which cannot be done today because the words of our languages are not sufficiently fixed or well enough fitted for good explanations without figures.[94]

While humbled by the trivial successes of such projects in the past, Leibniz still held to a grand vision:

> . . . although learned men have long since thought of some kind of language or universal characteristic by which all concepts and things can be put into beautiful order, and with whose help different nations might communicate their thoughts and each read in his own language what another has written in his . . .[95]

His vision extends previous philosophical languages into mathematics as well as both the political and phys-

[85] Hüllen, W., 1986. The paradigm of John Wilkin's thesaurus. In: Hartman, R.R.K. (Ed.), The History of Lexicography. Papers from the Dictionary Research Centre Seminar at Exeter. John Benjamins Publishing Company, Amsterdam, p. 117.

[86] Davis, M., 2001. Engines of Logic: Mathematicians and the Origin of the Computer. Norton, New York, p. 133.

[87] Dascal, M., 1987. Leibniz: Language, Signs and Thought, A Collection of Essays. John Benjamins Publishing Company, Amsterdam, pp. ix–xi.

[88] "Semiotics: the study of the properties of signs and signalling systems, especially as found in all forms of human communication". Crystal, D., 1997. The Cambridge Encyclopaedia of Language. Cambridge University Press, p. 436.

[89] Hintikka, 1997. Lingua Universalis vs. Calculus Ratiocinator: An Ultimate Presupposition of Twentieth-Century Philosophy. Kluwer Academic Publishers, Dordrecht; Kusch, 1989. Language as Calculus vs. Language as Universal Medium. Kluwer Academic Publishers, Dordrecht; Shin, 2002. The Iconic Logic of Perice's Graphs. The MIT Press, Cambridge, MA.

[90] Davis, M., 2001. Engines of Logic. p. 134. See also Dawson Jr., J.W., 1997. Logical Dilemmas: The Life and Work of Kurt Gödel. Wellesley, Massachusetts.

[91] We would also like to draw the reader's attention to a tantalizing symbolic diagram depicting the combination of environmental forces like wind and water, reproduced on page 83 of Loemker (Ed.), 1976. Gottfried Wilhelm Leibniz: Philosophical Papers and Letters, and invite the juxtaposition of such with H.T. Odum's modern Energy Systems Language.

[92] Leibniz in Loemker (Ed.), 1976. p. 250.

[93] Rutherford, 1998. Philosophy and language in Leibniz. In: Jolley, N. (Ed.), The Cambridge Companion to Leibniz. Cambridge University Press, Cambridge, p. 227.

[94] Leibniz in Loemker (Ed.), p. 250.

[95] Ibid., p. 222.

ical sciences. Moreover, it would be intelligible to anyone whatever language they know.[96] In this Leibniz believed it a novel project:

> ... no one has attempted a language or characteristic which includes at once both the arts of discovery and of judgement, that is, one whose signs or characters serve the same purpose that arithmetical signs serve for numbers, and algebraic signs for quantities taken abstractly.[97]

Like the various instruments used in the sciences, Leibniz says the *Characteristica Universalis* will be:

> ... an instrument even more useful to the mind than telescopes and microscopes are to the eyes. Every line of this writing will be equivalent to a demonstration. The only fallacies will be easily detected errors in calculation. This will become the great method of discovering truths, establishing them, and teaching them irresistibly when they are established.[98]

Leibniz held great hope that the project will forward human emancipation:

> ... it will be impossible to write, using these characters, chimerical notions (chimeres) such as suggest themselves to us. An ignoramus will not be able to use it, or, in striving to do so, he himself will become erudite.[99]

We can see Leibniz's semiotic sophistication in that he recognises the fundamental notion that the characters of language are arbitrary. Despite this Leibniz proposes that:

> ... their use and connection have something which is not arbitrary, namely a definite analogy between characters and things, and the relations which different characters expressing the same thing have to each other. This analogy or relation is the basis of truth.[100]

Ecosystem historian J. Hagen describes such a definite analogy as a "formal analogy", and identifies it with the synthetic practice of ecosystems ecology.[101] For Truitt and Rogers, reasoning by analogy, "discern[s] similarities between the variations of certain characteristics of ... seeming distinct devices and systems".[102] For Leibniz, such synthetic practice is, "... that science in which are treated the forms or formulas of things in general, that is, quality in general".[103] Elaborating on this notion Leibniz stated:

> Synthesis is when, beginning from principles and running through truths in order, we discover certain progressions and form tables, as it were, or sometimes even general formulae, in which the answers to what arises later can be discovered.[104]

"This", proclaims Leibniz of the *Characteristica Universalis*, "... is undoubtedly one of the greatest projects to which men have ever set themselves.[105]

4.3. Three criteria for the Characteristica Universalis

Leibniz never formalised any criteria for what would constitute the *Characteristica Universalis* in any of his readily available publications. However, in Cohen's view,[106] the universal character fulfils three main roles: (i) it would be what modern linguists call an "international auxiliary language", enabling men of different nations to communicate with one another; (ii) it would provide what Lewis calls a "logistic" treatment of science in general, a simplified system of symbolism for the exact expression of all actual

[96] Rutherford, 1998. p. 229.
[97] Leibniz in Loemker (Ed.), p. 222.
[98] Ibid., p. 261.
[99] Leibniz, cited in Davis, 2000. Engines of Logic. p. 16.
[100] Leibniz in Loemker (Ed.), p. 184.

[101] Hagen, J.B., 1992. An Entangled Bank: The Origins of Ecosystems Ecology. Rutgers University Press, New Jersey, p. 76. Moreover, Keller, D.R., Golley, F.B., see ecology as the science of synthesis, 2000. The Philosophy of Ecology: From Science to Synthesis. University of Georgia Press, Athens, GA, pp. 1–19.
[102] Truitt, T.D., Rogers, A.E., 1960. Basics of Analog Computers. J.F. Rider Publisher, New York, p. v.
[103] Leibniz in Loemker (Ed.), p. 233.
[104] Leibniz, G.W.v, 1683. Of universal synthesis and analysis. In: Parkinson, G.H.R. (Ed.), 1988. p. 16. Emergy theorists M.T. Brown, S. Brandt-Williams, D. Tilley and S. Ulgiati (2000) all recognise synthesis as, "the act of combining elements into coherent wholes". In: Brown, M.T. (Ed.), Emergy Synthesis: Theory and Applications of the Emergy Methodology. Proceedings of the First Biennial Emergy Analysis Research Conference, Centre for Environmental Policy, University of Florida, Gainesville, FL, p. 1.
[105] Leibniz in Loemker (Ed.), p. 259.
[106] Cohen, C.J., 1954. On the project of a universal character. Mind (New Series) 63 (249).

and possible knowledge; and (iii) it would serve as an instrument of discovery and demonstration. Here we will designate these three criteria as: (i) 'International Auxiliary Language'; (ii) 'Logistic General Science'; and (iii) 'Demonstrative and Discovery Implement'.

Hermeneutician[107] H.-G. Gadamer suggested that only through mathematical symbolism would it be possible to rise entirely above the contingency of historical languages and the vagueness of their concepts: "In the combinations of this kind of sign system, Leibniz believed, we would acquire new truths that would be of mathematical certainty . . . ".[108] Parallel to this suggestion is that of H.T. Odum, who attributes the 'new truths' acquired from the Energy Systems Language to a new way of doing mathematics. This he refers to as 'emergent theorems'.[109] In this connection, it is already clear that H.T. Odum's Energy Systems Language at the very least touches upon all three criteria. The discussion will now turn to an assessment of the degree to which H.T. Odum's Energy Systems Language satisfies these criteria and thus qualifies as an example of the otherwise unfinished *Characteristica Universalis* Enlightenment project.

5. Energy systems language as *Characteristica Universalis*

5.1. International auxiliary language

D. Rutherford cites Leibniz on the 'universal writing' enabled by the *Characteristica Universalis*: "The whole of such a writing will be made of geometrical figures, as it were, and of a kind of pictures—just as the ancient Egyptians did, and the Chinese do today".[110] Moreover, Cohen contends that through use of the *Characteristica Universalis*, ". . . scientists would be able to attain the same degree of rigour in metaphysics and morals as in geometry and analysis, and nothing chimerical would ever be written down".[111] Extending this notion further, Rutherford writes, that by utilising the *Characteristica Universalis*, ". . . it will become possible to reason in ethics and metaphysics with a degree of certainty hitherto only found in mathematics".[112] In fact, Ostwald believed that such a moral guide could be based on energy, describing it as the '*Energetische Imperativ*' (German: Energetic Imperative), and proposed a universal language to save efforts otherwise spent on translations between National dialects.[113]

In his introduction to Leibniz's philosophical writings, Loemker conceives the symbolic languages of mathematics and chemistry as 'real characters', whose symbolisms are specific to, and defining of, the phenomena of interest in those disciplines. For Loemker the *Characteristica Universalis* is literally a universalisation of such real characters. On this view the synthetic network diagrams (schematic language) of electronic circuitry are also a set of 'real characters', like the real characters of mathematics and chemistry, though specific to electronics. Identifying the electronic circuit language as another set of real characters affords philosophers access to the more universal and synthetic Energy Systems Language, another set of 'real characters'. This is particularly evident when it is noted that the Energy Systems Language was originally defined as a generalization of the language used to describe and design passive analog electrical circuits.[114]

Like its electronics counterpart the energy system language and its 'emergy' (i.e., EMbodied enERGY) formalisms[115] are becoming an international auxiliary language. That is, they enable scientists and

107 "Hermeneutics: the method of interpretation first of texts, and secondly of the whole social, historical, and psychological world". Blackburn, S., 1994. Oxford Dictionary of Philosophy. Oxford University Press, p. 172.

108 Gadamer, H.-G., 1975. Truth and Method. The Seabury Press, New York, p. 376.

109 Odum, H.T., 1994. Comments that from the use of the energy systems language, ". . . it was realized that the diagrams are themselves a form of mathematics with emergent theorems and perceptions for the workings of the mind that extend the capacity to see wholes and parts simultaneously". Ecological and General Systems, pp. ix–x.

110 Leibniz in Rutherford, 1998. p. 229.

111 Cohen, 1954. p. 50.

112 Rutherford, D., 1998. p. 231.

113 Martinez-Alier, J., 1990. Ecological Economics: Energy, Environment and Society. Basil Blackwell Ltd., Oxford, p. 184.

114 Odum, H.T., 1994. Ecological and General Systems: An Introduction to Systems Ecology. Colorado University Press, Colorado, p. 34.

115 Odum, H.T., 1996. Environmental Accounting: Emergy and Environmental Decision Making. Wiley.

engineers of different nations to communicate with one another. The universality of the Energy Systems Language, however, extends the realm of discourse to issues of great political, ecological and economic importance.[116] In this way the Energy Systems Language appears to qualify for Cohen's first *Characteristica Universalis* criteria.

5.2. Logistic general science

As suggested above, C.I. Lewis asserted that the *Characteristica Universalis* became the project of the logistic[117] treatment of science in general.[118] But Lewis also suggested that the absence of an existing *Characteristica Universalis* prevented cooperation towards just such a logistic general science.[119] Yet Leibniz had faith that the primitive concepts of this *Characteristica Universalis* were fixed in the nature of things.[120] Historian of mathematics, C.B. Boyer proposed that, "… Leibniz wished to develop a universal characteristic that would serve as a sort of algebra of logic".[121] As a logistic algebra, the *Characteristica Universalis* aimed to make logical discussions systematic, providing an end to philosophical controversies.[122] Importantly, the *Characteristica Universalis* went hand in hand with the development of the '*Calculus Ratiocinator*' (Latin: Token Calculator)—Leibniz's mechanism that allowed for easy calculation of his *calculus differentialis* (Latin: Differentiating Tokens) and *calculus integralis* (Latin: Integrating Tokens). In fact, N. Weiner considered Leibniz's *Calculus Ratiocinator* the forerunner to the modern day computing machine.[123] The development of the *Characteristica Universalis* itself might, therefore, only have become practicable with the concurrent development of the computer. Alternately, Leibniz suggested that if his *Characteristica Universalis* were completed the way he envisaged, "… one could carry out the description of a machine, no matter how complicated".[124]

Correspondingly, while the Energy System Language retains considerable utility in isolation from computers, with them, their capacity for simulation modelling confers substantial benefits to scientific progress. As P. Kangas writes: "… Odum began utilizing the operational analog computer for ecosystem simulation in the late 1960s".[125] In fact, this was critical for the development of the Energy Systems Language, as Kangas noted that it was "[a]s an outgrowth of conventional circuit diagrams used to describe passive electrical analog models, [that] Odum developed a symbolic modelling language … ".[126]

Whereas conventional circuit diagrams describe complex micro-computing machines, the Energy Systems Language, which describes ecological phenomena, is sometimes called a 'macroscope'.[127] The characters of this macroscope are predicated on an energetic systems ontology.[128] That is, the macroscopic characters designate entities such as the energy sources, flows, transformations, stores, and sinks that characterise the causal circuits of phenomena to be described. In giving expression to this ontology, H.T. Odum used the structure of passive electrical analogs to constrain descriptions of the relations between such

[116] See for instance, Lefroy, E. (Australia), Rydberg, T. (Sweden), 2003. Emergy evaluation of three cropping systems in southwestern Australia. Ecol. Model. 161, 195–211. Yang, H., Li, Y., Shen, J., Hu, S. (China), 2003. Evaluating waste treatment, recycle and reuse in industrial system: an application of the emergy approach. Ecol. Model. 160, 13–21. Brown, M.T. (U.S.), Ulgiati, S. (Italy), 1998. Emergy evaluation of the environment: quantitative perspectives on ecological footprints. In: Ulgiati, S. (Ed.), Advances in Energy Studies: Energy Flows in Ecology and Economy. Museum of Science and Scientific Information, Italy, pp. 223–240.

[117] "Logistic may be defined as *the science which deals with types of order as such*. It is not so much a subject as a method. Although most logistic is either founded upon or makes large use of the principles of symbolic logic, still as science of order in general does not necessarily presuppose or begin with symbolic logic". Lewis, C.I., 1918. A Survey of Symbolic Logic. University of California Press, Berkeley, p. 3.

[118] Ibid., p. 9.

[119] Ibid., p. 7.

[120] Ibid., p. 8.

[121] Boyer, C.B., 1991. A History of Mathematics. Wiley, p. 407.

[122] Ibid.

[123] Weiner, N., 1948. Time, communication, and the nervous system. Teleological mechanisms. Ann. N.Y. Acad. Sci. 50 (4), 214.

[124] Leibniz in Loemker (Ed.), 1976. p. 250.

[125] Kangas, P., 1995. Contributions to Ecosystem Simulation Models. In: Hall, C.S. (Ed.), Maximum Power: The Ideas and Applications of H.T. Odum. Colorado University Press, Niwot, CO, p. 14.

[126] Ibid., p. 15.

[127] Odum, H.T., 1971. Environment Power and Society. Wiley Interscience, pp. 9–11.

[128] Ontology: the science of being. Lowe, E.J., 1995. Ontology. In: Honderisch, T. (Ed.), The Oxford Companion to Philosophy. p. 634.

entities to only those descriptions that conform with the principles of ecological energetics. This is possible because the structure of passive electrical analogs presuppose, and indeed instantiate (i.e., operate in accordance with), what Kangas has called a "Network epistemology".[129,130] More recently Habermas has recognised the importance of the Network concept for philosophical languages as "constitutive for processes of mutual understanding"[131] of the macroscopic flows of commodities, capital, information, and "the circulatory process between humanity technology and nature".[132] Thus a Network epistemology coupled with an energetic ontology would seem to provide a firm basis for the development of a general logistic treatment of science, in accordance with Leibniz's *lingua philosophia*.

On Cassirer's view Leibniz's linguistic philosophy is derived from Aristotle, where "every predication presupposes an ultimate point to which it refers. Substance ... is this ultimate point; it underlies all predication ... ".[133] That is, 'substance' is what 'fixes' the language. For Quantum physicist Max Planck, one of the few propositions that remained a "firm point of origin ... [was the] ... universal energy principle".[134] When we supplement this with Boltzmann's proposal that every predication in Leibniz's writing concerning the 'substantiality of force' actually refers to 'energy', we find that the *Characteristica Universalis* was to be fixed in the *energetic* nature of things. This is precisely the 'logistic' approach taken by H.T. Odum's Energy Systems Language, which involves a rational syntax for the ordering of characters on their energy types and transformation ratios. As Kangas writes in an insightful essay: "... the most important feature of the passive electrical analog may have been that it physically contained the constraints of the energy laws".[135] Quoting H.T. Odum, Kangas continues,

> Odum felt this was important in a modeling language because 'wild options of creative mathematical thinking are thus severely restricted by energy constraints'.[136]

Thus, in the Energy Systems Language, chimerical notions and models are avoided because energy constraints underlie every predication of types and order of energy transformations and flow. This treatment appears to qualify the Energy Systems Language for Cohen's second *Characteristica Universalis* criteria.

5.3. Discovery and demonstration implement

With the Energy Systems Language, H.T. Odum developed models that allowed a number of discoveries and demonstrations using the approach of our heralded *unitas multiplex*. In this H.T. Odum and E.C. Odum recognise, "how similar all the branches of knowledge are, often using similar functions under different names".[137] For example, H.T. Odum and colleagues have, "... developed the concepts and demonstrations of using self-design processes (ecological engineering) to recycle wastewaters to wetlands".[138] Moreover they also demonstrated the "... causal role of the network reinforcement that we call the Maximum Power Principle".[139] By doing so, H.T. Odum came to a general science of energy quality, that is 'emergy'.[140] Emergy, to paraphrase H.T. Odum and E.C. Odum, is a tabulation of the energy of one type required directly and indirectly to make a service or product.[141] Indeed, it was from tabulating emergy flows that H.T. Odum discovered what he called the "maximum empower principle",[142] which he proposes as a guideline

[129] Kangas, P., 1995. p. 15.
[130] Epistemology: the theory of knowledge. Hamlyn, D.W., 1995. "Epistemology, history of". In: Honderisch, T. (Ed.), The Oxford Companion to Philosophy. Oxford University Press, Oxford, p. 244.
[131] Habermas, J., 1987. Excursus on Luhmann's appropriation of the philosophy of the subject through systems theory. In: Habermas, J. (Ed.), Lawrence, F. (Trans.), The Philosophical Discourse of Modernity: Twelve Lectures. The MIT Press, Cambridge, MA, p. 380.
[132] Habermas, J., 2001. In: Pensky, M. (Ed.), The Postnational Constellation and the Future of Democracy. p. 66.
[133] Cassirer, E., 1942. p. 312.
[134] M. Planck in Deltete, 1997. Vol. I, p. 118.
[135] Kangas, P., 1995. p. 15.
[136] Ibid.
[137] Cassirer, E., 1942. p. xvii.
[138] Odum, H.T., 1995. p. 369.
[139] Ibid., p. 315.
[140] Ibid.
[141] Odum, H.T., Odum, E.C., 2000. Modeling for All Scales, pp. 152, 154.
[142] Odum, H.T., 1995. Self-organization and maximum empower. In: Hall, C.S. (Ed.), Maximum Power: The Ideas and Applications of H.T. Odum. Colorado University Press, Boulder, CO, p. 319.

for selecting policy: “Choose alternatives that maximize empower intake and use”.[143]

H.T. Odum’s proposal that political decisions be based on considerations of their consequences for the flow of emergy (i.e., empower) brings together what Leibniz called the “kingdom of wisdom” and the “kingdom of power”. Leibniz conceived these domains of human activity as permeating each other so that “the maximum in the kingdom of power, and the best in the kingdom of wisdom, take place together”.[144,145] In using the Energy Systems Language, H.T. Odum inadvertently consolidated Leibniz’s synthetic view. To paraphrase Leibniz, when beginning from principles, running through truths in order and forming tables we may discover certain progressions. Thus, we may end philosophical controversies by calculation using a *calculus ratiocinator* (either analog or digital computer, or both) embodying the *Characteristica Universalis* (*qua* Energy Systems Language).[146] These considerations clearly qualify the Energy Systems Language for Cohen’s third criteria.

6. Conclusions

This essay has explored the degree to which H.T. Odum’s Energy Systems Language qualifies as an example of G.W.v Leibniz’s unfinished Enlightenment project, the *Characteristica Universalis*. H.T. Odum and Leibniz, have been shown to share the aims of *philospohia perennis* and the approach of *unitas multiplex*. Furthermore, it was demonstrated that Leibniz contributed substantially to much of the background material eventually systematised in H.T. Odum’s Energy Systems Language. This was shown to include cybernetics, mathematical biology, and energetics, all of which are fundamental to ecosystems ecology.

With respect to our main thesis, the Energy Systems Language was evaluated against three criteria for the *Characteristica Universalis*. It was argued that the Energy Systems Language satisfies the ‘International Auxiliary Language’ criteria, in that it enables scientists and engineers of different nations to communicate with one another on issues of great political, ecological and economic importance. The Energy Systems Language was also seen to qualify for the ‘Logistic General Science’ criteria in that the characters are predicated on the principles of ecological energetics. Furthermore, Energy Systems Language seemed to easily pass the ‘Demonstrative and Discovery Implement’ criteria, particularly in that it has been utilised for simulation modelling and has lead to the discovery of the “maximum empower principle”. Regardless of the degree to which our evaluation holds—that the Energy Systems Language is a *Characteristica Universalis*—the connection between the lifework of H.T. Odum and G.W.v Leibniz remains intriguing, and in need of further attention by philosophers and scientists alike.

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[143] Odum, H.T., Odum, E.C., 2001. A Prosperous Way Down: Principles and Policies. Colorado University Press, Boulder, CO, p. 71. See also Odum, H.T., Emergy evaluation. In: Ulgiati, S., 1998. Advances in Energy Studies: Energy Flows in Ecology and Economy. Museum of Science and Scientific Information, Roma, p. 99.

[144] Leibniz in Loemker (Ed.), 1976. p. 442.

[145] Horkheimer and Adorno write, “The awakening of the self is paid for by the acknowledgement of power as the principle of all relations”. Horkheimer, Adorno, 1969. p. 9.

[146] See, for example, the computer modeling program EXTEND™ as used in H.T. Odum and E.C. Odum (2000).