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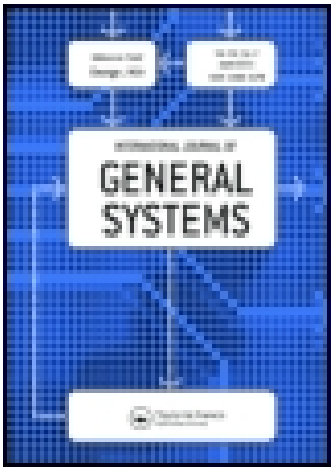

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The reflection of life: functional entailment and imminence in relational biology, by A. H. Louie

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BOOK REVIEW

The reflection of life: functional entailment and imminence in relational biology, by A. H. Louie, Springer, New York, NY, 2013, xxxii + 243 pp., ISBN 978-1-4614-6927-8

Quo vadis relational biology?

> … he who increases knowledge increases sorrow
>
> *Ecclesiastes 1:18*

In our days, we can read about a "Rashevsky-Rosen-Louie school of theoretical biology" (Naranjo 2011). For those active in academia, this is a moment of satisfaction. Students attain the rank of their masters. Indeed, A.H. Louie deserves the promotion; his work is acknowledged. A special issue of *Axiomathes* (volume 21, issue 2, June 2011) was dedicated to his previous book, *More Than Life Itself: A Synthetic Continuation in Relational Biology* (2009). Prideaux (2011) calls it a "monumental achievement … laying out the ground work for the theoretical development of relational biology". Louie is invited to speak at various conferences and to publish. His determination to continue in his teacher's path, and further develop relational biology, is a matter of record.

Without intending to dampen the justified celebration of his work, I shall quote his mentor: "… if I were to disappear, there's nobody who could appear to do what I do" (Rosen 1997). Why did Rosen not pass the baton to his best student in this interview? We can only speculate. One possible answer: Rosen knew how difficult it would be to continue a line of thinking met with hostility during his lifetime. His position does not align with the dominant view of biology (Rosen 1991, 13):

> Why could it not be that the "universals" of physics are only so on a small and special (if inordinately prominent) class of material systems, a class to which organisms are too *general* to belong? What if physics is the particular, and biology the general, instead of the other way around?

In our days, the outlook for Rosen's visionary work is improving. The reductionist approach is still the dominant research direction, but the world of science is opening up to alternatives. Leaving aside the hyperbole in a well-intended title "Robert Rosen (1934–1998): a snapshot of biology's Newton" of the paper by Mickulecky (2001), quite a bit of evidence speaks in favour of a late recognition of his ideas. Casti (2002) wrote: "The work of Rosen will keep scholars busy for decades". Others, for example Letelier, Marín, and Mpodozis (2003) and Letelier et al. (2006), after writing about "40 years of obscurity", seem to predict interest in Rosen's ideas for at least as long in the years to come.

An invitation to the reader, wondering what the above-given Rosen memento has to do with Louie's second book, the subject of this review: please be patient. A first answer is easy to formulate: Louie contributes substantially to a rekindling of interest in the work of his professor. Probably I was not the only one to be touched upon reading the last line in the book,

"I should have liked to have shown this book to Robert Rosen" (235). Please read this line carefully. It is an unusual formulation, characteristic of Louie's writing, conveying respect, but also a sense of autonomy. To show the book is not the same as asking for approval! Authentic scholars are capable of both humility and arrogance. Rosen himself had both.

The second answer is more pedestrian. Louie is not writing a biography of Rosen – although he evidently could. (For the record: time and again I consulted with him since he is, to the best of my knowledge, a "living" repository of information pertinent to Rosen's activity.) Louie continues Rosen's thinking, occasionally pointing to publishing errors, but usually making sure that those who do not understand his teacher's concepts do not end up remaking his legacy from their own perspectives or to suit their own purposes. This later function of vigilant caretaker is not easy. Let's recall one specific episode: Chu and Ho published an article in order to "review the essence of Rosen's ideas leading up to his rejection of the possibility of real artificial life *in silico*". (Chu and Ho 2006, 117). Louie debunked their take in a decisive manner: "they use a wrong definition of Robert Rosen's mechanism. This renders their 'critical assessment' of Rosen's central proof null and void" (Louie 2007, 293). One would hope that Louie's clear demonstration will suffice to put the aberration, together with those who promoted it, out of commission. Unfortunately, as we know from the history of science, misrepresentation is resilient. The debunked text is still used as an argument for defending exactly the viewpoint on life that Rosen criticized; see, for example, Chemero and Turvey (2006), among others.

But regarding this last observation, let us make one idea clear: Louie elaborates *his* understanding of relational biology. He is not an epigone, but rather an original thinker to be considered in his own right. The premise of his investigations is clearly stated: function dictates structure. Moreover, his approach is informed by Rosen's famous axiom, "A material system is an organism if and only if it is closed to efficient causation" (Rosen 1991, 244). (He and I might debate whether "axiom" is the right word here or in other places where Louie uses it.)

The structure of Louie's two books is relatively similar. I will not review the first book; George Klir (who also deserves credit for publishing the book I discuss here) reviewed it quite aptly in this journal (Klir 2010). A quote from the review is justified since in many ways it applies to the book under discussion here:

> The book presents the material at two levels, a level of conceptual/philosophical discussion and a level of rigorous mathematical treatment. Understanding the latter requires substantial mathematical maturity. I suspect that the most challenging aspect of the book for many readers will be the heavy use of category theory, which plays an important role in Rosen's system theory. Although requisite mathematical preliminaries are concisely presented in the book, more extensive knowledge, especially in category theory, is likely to be needed for full understanding of the material covered. (783)

Others have offered quite impressive discussions of what the book achieved. Louie himself states that his first book addressed the epistemology of life, focused on one (M,R)-system. His new book addresses "the ontogeny of life as well as how life evolves from the singular to the plural" (vii), focused on two interacting (M,R)-systems. Maybe this very condensed description can be expanded a bit to include the subject of Part III of the book: Interacting (M,R)-Networks. None of his readers would be surprised if, in the years to come, the sequence of books will be continued. For now, one observation: the two books ought to be considered together. Many subjects are alluded to in the elegant exposition, almost like a promise to revisit one or another still not fully elaborated intuition.

Louie identifies himself as an outlier ("next peaks to be scaled", 234) and ascertains that "The Book of Nature is written in the language of mathematics" (ix). Of course, since φύσις

Figure 1. A symbol for the forked arrow. The symbol can be deployed in a variety of applications (Louie 2013, 29; reproduced with permission).

(*physis*, Gr.) is an ancient name for nature, nobody will object to this statement. (It was actually formulated by many, but also rejected by many, Aristotle among them.) For reasons discussed in both of his books (and previously by Rosen himself (1993), the mathematics is that of category theory. Others argue that algebra (Pearl 2009) or geometry (Dellian 2012) is the language of nature, but this should not undermine the justification for adopting category theory. (In Rosen's autobiographical notes, the subject gets all the relevant details, including the statement that he was the first to use it.) Louie is able to convince the reader that the meta-level of discussion, characteristic of relational biology, justifies the selection of a meta-level mathematical theory. Experimental biology is "dirty", it implies "feet on ground"; relational biology is axiomatic. Louie knows his mathematics, he "thinks" in categories. Notwithstanding, the book is way more than a respectable category theory elaboration. In need of additional elements supporting his mathematics, he does not hesitate to introduce new operations – those pertinent to the category of relations are but one example – and symbols. One example is shown in Figure 1.

Chances are good that practitioners of category theory will find Louie's contributions to the language of category theory useful. No theory survives if it does not keep pace with change.

In *More Than Life Itself*, the reader was exposed to partially ordered sets, lattices, graphs and, of course, categories. *The Reflection of Life* restates Louie's expectation of the readers' familiarity with set theory, without shying away from defining a shared mathematical vocabulary. This vocabulary includes sets and subsets, the power set, the relative complement of a set, equipotence (and the Law of Trichotomy of Equipotence), cardinality, Cantor's Continuum Hypothesis, indexed sets and partitions, and sequences. Those conversant in mathematics might find part of this effort at definition superfluous. The profile of potential readers justifies the author's insistence on a shared vocabulary. Professionals active in biology are usually not only mathematically illiterate, but also adverse to mathematics. (The profile of mathematicians, in particular those interested in biology, is a bit more difficult to describe. We shall return to this when discussing reactions to Louie's writings.) In addition to the Cardinalis (actually *Prolegomenon: Cardinalis*), the book deals in set-valued mappings, adjacency matrices, random graphs and interacting entailment networks. The "scaffolding" effort takes two-thirds of the entire constructive effort represented by the book. It is clear, concise and to the best of my understanding free of formal errors.

In the age of the Internet and social media, it is not at all difficult to find out how various readers (or those who refused to read the book) react to such a book. Louie has gained a small group of respectful readers, who signalled to each other that a new book under his signature was issued. One reaction was telling (I will not reproduce the exact words): *The author uses too much mathematics. Rosen was more given to an expository style* [italics mine, to suggest that this was the idea expressed]. This particular reaction deserves attention because at the time Rosen published his work, he was also accused of using too much (and too esoteric) mathematics, compared to Rashevsky's prose. How times change! Computational formalism is probably the next threshold. Indeed, if a group critical of Louie's take can be identified, it is that of the practitioners of computational science focused on biology. Definitely, their arguments will have to be considered in direct connection to his new findings.

Louie's mathematics is solid. He proceeds along the line of establishing a formal framework, within which deduction is the dominant method. In my view, the most powerful pages are those under the heading "Exordium". The Latin in this text is part of the architecture of thought, and therefore it deserves more than being incidentally mentioned – yet another subject begging for some delayed attention. (Parenthetically: an *Exordium* is supposed to define the argument, justify the style, introduce the speaker and name the opponent. I wish Louie had paid attention to this structure because it would have helped him avoid frequent digressions. About the style – supposed to avoid the exotic or the over-laboured – more in the last part of this review.)

The mathematics is interwoven with the metaphysics informing Louie's science. Causality means Aristotle's four causes – no compromise in sight (even in the sense of mentioning alternatives). Relational biology harks back to Rashevsky's anti-reductionist view of 60 years ago: throw away the matter and function determines structure. Start at the most abstract level: reality is an expression of mathematics, a realization (among very many possible). The broad interrogation (reductionism and non-reductionism) and the method to address it (mathematical formalism) recall the irreconcilable nominalism/realism positions. The views collide in a very specific way: each is justifiable, and each advances answers that the opposite view could not give. Against this background, what justifies Louie's attempt is the wise realization that "one world is not enough" (xxi).

Relational diagrams and mappings, his preferred tools, are creatively deployed in describing the efficient cause, i.e. what makes change in the living possible. From the Greek *kinetikos* to the Latin *efficare*, there is not so much a translation effort as an epistemological journey. To put in motion (for a long time, change was seen as an expression of motion) is less than to bring into existence. For mathematicians, the Natural Law axiom – "Every process is a mapping" – is at least intuitive. Natural processes and mappings are set in correspondence with the intention to "data mine" knowledge from the mappings, not from "smelling the roses" (if I may put it this way instead of the commonplace "getting his hands dirty"). A sequential composition can evolve into a sequential chain. The sequential cycle corresponds to the linking of the initial and the final mappings in the chain. Take note of Louie's graph-theoretic representations (Figure 2): the hollow-headed arrow denotes a constraint upon the flow (in Rosen's words: relations of material causation, 1991, 244); the black arrow defines relations of efficient causation.

This visual treatment of entailments (which I present in a simplified form) is not only illustrative, but also gnoseologically productive. The labelling bears witness to the characterization,

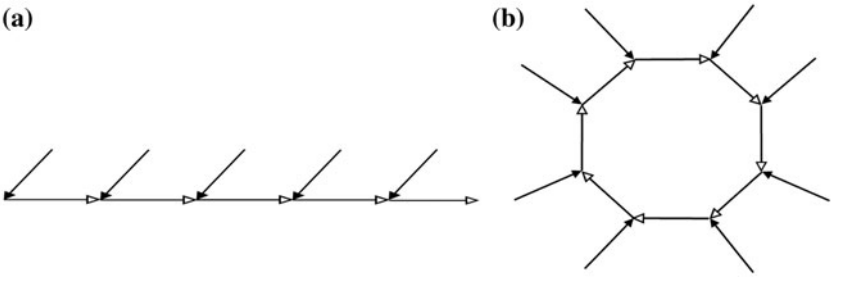

Figure 2. (a) Sequential chain of linked mappings. (b) Sequential cycle (final and last mappings in the chain are linked). This represents a closed path of material causation (Louie 2013, xxv; reproduced with permission).

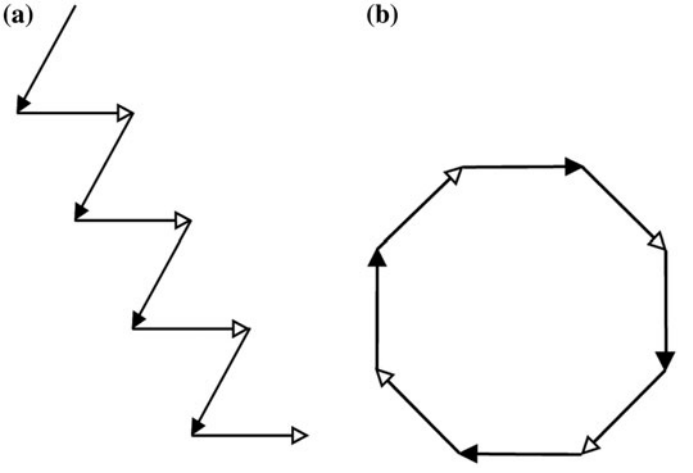

Figure 3. (a) Hierarchical compositions from a chain; (b) Hierarchical cycle. "Efficient cause relayed" – a hierarchical cycle is a closed path of efficient causation (Louie 2013, xxv; reproduced with permission).

"A sequential cycle may … be called a closed path of material causation" (xxiv). Using a similar line of argument, Louie defines a hierarchical chain and the corresponding hierarchical cycle (the topological dimension of the argument should not go unnoticed). Albeit, the real move forward in the formal argument is supported by *impredicativity* – a stepping stone that plays a critical role in the whole book. In a private communication some years ago, Kercel[1] drew my attention to the role impredicativity plays in Rosen's attempt to describe anticipatory processes. In Louie's book, impredicativity ends up characterizing the living as non-simulable (i.e. not definable by an algorithm in Turing's sense). Whether it was his intention or not to land in the territory of self-reference, or better yet in Gödel's world, is not for a review to ascertain. To predicate is to assert something (a property, for instance) about something else. Self-referencing is by its nature circular (by definition, it cannot be otherwise), and results in impredicativity – either of definitions or in behaviour.

It comes as no surprise therefore that Rosen's (M,R)-system (Metabolism-Repair System) is by necessity being mapped into a hierarchical cycle (Figure 3).

The figures shown are the sequential chain and the folding into a sequential cycle (Figure 2(a) and (b)) and, respectively (Figure 3(a) and (b)), the hierarchical chain and the folding into a hierarchical cycle (xxii–xxv). From here on, there's no red light to stop the flow of the argument: life (the organism being its prototypical expression) is closed to efficient causation. Its realization can only be in the form of an (M,R)-system. (This is the "Postulate of Life", xxxii).

Readers with enough motivation to follow the line of reasoning are asked not only to accept its formal accuracy, but to adopt this premise as well. The book's axiomatic manner is the expression of its strength, but also of its weakness. In some very dignified way, this is a dogmatic viewpoint; but for that matter, each attempt at opening a new perspective is dogmatic (and in contradistinction to dogmata). In the jargon of contemporary innovation fervour, it can be qualified as "disruptive" instead of dogmatic.

But that is only one part of Louie's contribution. Another part corresponds to his attempt to build upon Rosen's famous modelling relation (a subject discussed in Louie's previous book). Those familiar with Rosen's work will easily understand that the relation between the

natural domain and the formal mapping of the natural has to be completed through a question: Is there anything that connects causal natural processes and all those inferences that can be generated by examining the formal domain? In my own understanding of modelling and its role in science, this is the most difficult of all questions, going well beyond the convenient encoding–decoding operation that Rosen and his followers adopted. The so-called "functional correspondence encoding", dealing with the relation between causal entailment (in the living) and inferential entailment in the formal representation, deserves more of Louie's attention. Pages dedicated to *Causality and Inference* (113 and following) are only a beginning. To be upfront: this is a review of Louie's book, not a subterfuge for arguing with a premise (in Rosen's original treatment) that is at best a compromise. Inference and entailment belong to different domains. (Only as a suggestion: representations are always also formative, and as such they change the system within which, or outside of which, they are produced, Nadin 2014b.) As inadequate as the premise is – Louie might not accept this view – he operates within its confines, not noticing that the circularity of self-reference eventually contaminates his own argumentation. An example:

> 7.1 Lemma: A natural system has a model containing a hierarchical cycle if and only if it has a closed path of efficient causation.
>
> 7.2 Theorem: A natural system is closed to efficient causation if and only if it has a model in which all efficient causes are involved in hierarchical cycles.

Besides the "are involved" (in reference to efficient causes) applied to a model, there is no knowledge derived – even less when a new formalism is introduced. For example, in *clef systems*, the semantics of the "verbose 'closed-to-efficient-cause-system'", *clef* becomes even more important because – hélas! – it means "key" in French. Relational descriptions are neither closed nor open to efficient causation. As mappings, they'd better carry information about the specific dynamics of the living they are maps of.

Finally, there is the third component of the discourse, and this is complexity. In *complexitas viventia producit*, *producit* stands for "brings forth", the expression Kauffman (1995, 2008, 2011) associates with Heraclitus in addressing natural entailment (seemingly "the world bubbles forth"). Within this last aspect, Louie is carried away by an impetus to pomposity: "I now declare that this 'organization chart' (Rashevsky's description of the representation of relations between the different biological functions of an organism) is the imminence mapping" (151). The peculiar declarative style should not prevent the reader from confronting the hypothesis. We are now in combinatorial mathematics, and the probabilistic method is brought up (under the very expressive quote (in which a typo insinuates itself, 141) from none other than Laplace's *Théorie Analytique des Probabilités*. In fairness to Louie, the exposition is terse but clear, with many definitions – but no proofs. The formal aspect is quite well rendered, but the entire construction – including rather difficult-to-defend assertions about "Incompleteness as Metaphor" (*sic*!) – is rather tautological. As a reader (with paper and pencil at hand), I realized that the author is patiently preparing for the most important section, dedicated to the "Interacting (M,R)-System". No doubt the implications are many. Pathophysiology (of the abnormal), natural selection, origin of life and virology (mentioned by the author) will gain from what the book makes explicit on account of its premises. Those (many) who will not forgive Rosen for having ignored the expectation of providing examples do indeed have enough to argue about here. Louie gives examples. Encouraging is the explicit understanding that relational biology invites itself to "hot problems", some aggravated within the reductionist perspective (where sometimes the medicine is worse than the disease).

Very convincing is the "Natural Philosophy of Symbiosis", in particular "Metabolism Symbiosis". The mathematics is clear and the associated discourse keeps close to the subject. A prediction can be made: to the extent that those already less than positively inclined to entertain the major premises of relational biology will read Louie's new book, they will react negatively. He does not mince words: "… attempts at the fabrication of life – will not work". Period! This straightforward attitude guides the discussions of the Anthropic Principle and of the origin of life.

Obviously, it is not easy to do justice to a book that sets quite a high threshold in the current dialogue on "What is Life", entailment, the role of computation in the acquisition and dissemination of knowledge, and the future of humankind. If indeed, "Le style c'est l'homme", the personality we encounter is not the traditional member of academia acting under the pressure of "publish or perish". Louie is an independent thinker quite impervious to what others think or write about him: "The diligent one sings for oneself, not for the recruitment of an audience" (he quotes, in *More Than Life Itself*, from a Chinese couplet, cf. xxi).

On this note, and without suggesting that Louie's book should have been anything other than what it is, I propose some critical aspects for his research agenda. One is complexity (alluded to above). Agreeing with Rosen's broader pronouncements is not enough. My choice was to adapt Gödel's decidability criterion (introducing G-complexity as a characteristic of the realm of the living (Nadin 2014a). The need for an operational definition of complexity stems from the understanding that complexity is a premise for the expression of anticipation (treated in his first book, and alluded to in his second). But regardless of anticipation, complexity considerations, more than anything else, connect to the computability aspects of (M,R)-systems. A definite effort of appropriating the powerful description of the living as a computable procedure resulted in many attempts to suggest that equivalence between the descriptions made using category systems and descriptions made using hyperset theory, RAF sets (Reflexive Auto-Catalytic Systems), process algebra Bio-PEPA, etc. We are beyond the moment of denigration (à la Landauer and Bellman 2002; and even Chu and Ho 2006, 2007a, 2007b, mentioned above). A clever semantics is practiced: if the fundamental statement regarding closure to efficient causation can be modelled, for instance, as hypersets, then life is a computation, since hypersets are Turing computable. Wells (2006) "in defence of mechanism" commits a similar error. One more example (Mossio, Longo, and Stewart 2009):

> … it may well be that a full model of "life itself" is not computable; but if so, the reason would *not* be the closure to efficient causation as expressed by Rosen. In fact, as we have shown, an equational presentation such as Rosen's *naturally* leads to λ- calculus terms, a paradigmatic functional frame over *discrete data types*. Biological invariance is turned into perfect computational iteration (this is at the core of discrete computation and λ-calculus in particular, under the form of recursive definitions). And to reiterate our conclusion, the fact that closure to efficient causation is computable, according to a standard mathematical definition of the term, in no way disqualifies it as a fundamental contribution to a theoretical definition of life.

It may well be that it is not computable, but if it is computable, it is still "a fundamental contribution". It is difficult to handle this kind of logic. Let us be clear: if closure to efficient causation (cf. Figure 4) were to be Turing computable, the "fundamental contribution" would be none.

This kind of narrative pretending to be scientific is actually modern sophistry, not unheard of, but rather disappointing. Rosen's category theory-based representation does not invite such speculations. The new mythology of computation and the associated infatuation with big data are more an expression of epistemological primitivism than the visionary opening it claims to be. The profile of mathematicians and computer scientists interested in biology, which I promised to

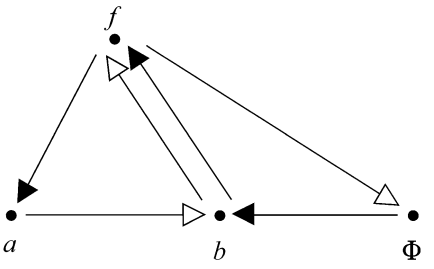

Figure 4. Rosen's relational model of closure to efficient causation. Hollow arrows represent relations of material causation; black arrows represent relations of efficient causation (Louie 2006, after Rosen 1991; reproduced with permission).

return to, recalls those who produce the mathematics and computation of poetry, but who cannot understand why Shakespeare's sonnets or even Robert Frost's poetry can profoundly touch readers (those few who still indulge in the pleasure of reading poetry).

Of course, within a review of Louie's book, such a tangential note cannot be followed by a formal demonstration of why shifted semantics is nothing but posturing. Louie correctly defines the algorithm (a term he does not feel is worth indexing!), and gives the notion of *simulable* a strict understanding. Those who push algorithmic computation miss a fundamental realization: the Turing machine embodies the reductionist thought (after all, Turing proved that Hilbert's *Entscheidungsproblem* cannot be solved, and that axioms, from which, in principle, all mathematical truths could be deduced, do not exist). If Rosen's anti-reductionist philosophy, embodied in the (M,R)-system, has any meaning, it could not be forced through semantic speculation to a reductionist view, even if the computation occasionally returns values that seem to confirm the premise. The hierarchical cycle (see Figure 3(b)) is not simulable. Therefore, I dispute Louie's generous (or polite) comment on SPICE (Simulation Program with Integrated Circuits Emphasis) or on the progress of computation – of course, not a subject in this book. Analogous circuits were already in use when I studied computers (way back in the early 1960s). The hierarchical chain modelled, using network thermodynamics, can be explained through circuit simulation under the assumption (correct for the non-living) that the laws of thermodynamics apply. The analogy of electric circuits–biochemical pathways contributes little if anything to the confirmation that (M,R)-systems are closed to efficient cause. In full awareness of the fact that, from among his reviewers, I might be at times the closest to his views, but at other times quite adverse, let me identify complexity in particular as the domain where we probably do not see eye to eye. On account of this disclosure, I was surprised that Louie remains rather tentative in discussing Rosen's stringent uncompromising position (though Rosen left some debt regarding the subject of complexity).

The conversation with Prideaux and the lines on the halting problem, especially the deadlock problem (different in natural processes from computer deadlock), are indicative of the need to explore the issue at depth. By no means would I take it upon myself to suggest answers. Rather, I hope Louie will look for them. Turing computation (i.e. algorithmic) corresponds to the level of "simple machines". That other forms of computation (such as interactive computation, cf. Peter Wegner's work on the subject) are possible, moreover that computation (in the broadest sense) and complexity are not incompatible, are subjects deserving attention. This is a make-or-break aspect of the entire discussion of relational biology! Louie's work has so far produced conceptual arguments in this sense.

Against this background, once again, it is worth asking the *Quo Vadis* question because *The Reflection of Life*, in conjunction with *More Than Life Itself* projects a sense of future. Cliff Joslyn, whose review of Rosen's *Life Itself* qualifies as one of the closest to understanding the conceptual revolution that the book triggered, provided a good historic background: "… three hundred years of science has been dedicated to the idea that the special class of simulable systems is in fact a universal paradigm for explanation of natural phenomena" (1993, 399). Despite the recent interest in Rosen's work and despite Louie's spectacular attempts at furthering the original views of the "framers", the ascent towards a shift from reductionism to a holistic view remains steep. My hope is that future work will *finally* address determinism. We do not want to abdicate a causality-based understanding of the living, but determinism is not the answer. Non-deterministic processes, characteristic of organisms, merit more attention.

More than once in my academic life, students asked me what good does it do to know Latin. (Just as an aside: some asked what good does mathematics do, before writing a successful app or launching a crowd-sourcing venture). I know an answer: Latin will help you understand where Aloysius H. Louie comes from in the profound sense of origins that are not just geographic, but spiritual. I refrain here from giving to the Latin subtitles all the associations they bear. I am grateful to the writer for framing his ideas as part of who he is in a broader sense. The spiritual dimension explains his intransigence, but also the lessons of a generic pilgrimage. This is a long journey, with many "stations of the cross", if I may make such an analogy. The more Louie discovers in the mappings on which he masterly operates, the more he becomes aware of his own wholeness: the researcher cannot be separated from the person, the culture, the civilization, the faith, the emotion and the values. I promise to remain a reader for as long as in my very embodiment closure to efficient causation is not superseded by mere material entailment.

Acknowledgements

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Note

1. See his joint paper with Louie on topological descriptions of living processes: (Louie and Kercel 2007).

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