Systems and Relations All the Way Down, All the Way Across

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If the aim of a third-order cybernetics is to extend its reach to a fully relational account, from the essentially ecological nature of so-called physical reality through to an associated relational hermeneutics of meaning, then what appears to be at stake is nothing less than the ontological question, considered as abstractly or broadly as possible: what is the nature of reality? More parochially, and as implied by the intermixing, here, of the scientific/technological realm of ecology and cybernetics and the poetic realm of hermeneutics and meaning, architecture comes to be dis-covered or re-engaged into where it has in reality always sat, namely as a (taught, professional, creative) discipline that transcends the two cultures of science/technology and poetics/meaning.[1] Or rather, it undermines those gross strata of thought by means of an ongoing praxis both in the academy and the practice of architecture.[2] In this it is nothing special: we are at a turn in culture where *any* discipline that is moving forward is going the same way by positively conjoining these two paths where possible, and radically undermining the dichotomy where necessary.

John Bruni (a researcher on the relations between literature and science) summarises the past history of cybernetics by reference to the Macy conferences. These conferences, held annually from 1946 onwards until the 1960s, brought together all the main contributors to cybernetic theory. He states:

> concepts such as information and feedback allowed the Macy Conferences to act as a catalyst for second-order systems theory, when first order, steady-state models of homeostasis became supplanted by those of self-reference in observing systems … According to N. Katherine Hayles, the conferences' singular achievement was to create a 'new paradigm' for 'looking at human beings … as information-processing entities who are essentially similar to intelligent machines,' by routing Claude Shannon's information theory through Warren McCulloch's 'model of neural functioning' and John von Neumann's work in 'biological systems' and then capitalising on Norbert Wiener's 'visionary' talent for disseminating the 'larger implications' of such a paradigm shift.[3]

This quotation comes from Darrell Arnold's summary book on systems theory, where in most contributions (for instance in architect Ranulph Glanville's piece) general systems theory and cybernetics are aligned and the differences between them elided.[4] Such differences nonetheless remain, and are neatly framed by physicist Egon Becker and ecologist Broder Breckling in their aptly-titled 'Border Zone Between Ecology and Systems Theory' where they state that:

> Cybernetics is not merely a special case of General Systems Theory, nor has cybernetics ever developed fully within systems theory. The idea of circularity as a fundamental principle turned into the notion of 'circular causality' in the broad theoretical outline of cybernetics. Cybernetics thus acquired its own discursive order, shaped by questions concerning regulation and information transfer.[5]

I have a slight unease with the name cybernetics, coming as it does from the Greek term for 'governor', and a similar unease (in this context) with the notions of regulation and human beings as information-processors. I will therefore refer mainly to 'general systems theory', also because this essay will engage with the inventor of this term, Ludwig von Bertalanffy.[6] Whatever the name, what is essential is the bringing together of deep relational accounts of reality, the undermining of linear causality, the primacy of 'information' (the exact status of which is to be clarified in this essay), and the notion of general system, which, viewed in the most abstract terms possible, implies essentially mobile arrangements (*agencements*), assemblages and ecologies.

As the use of such terms as *agencement* and assemblage imply, I will outline an ecologically informed ontology extending to the field of philosophy. I will argue that the work of Gilles Deleuze and Félix Guattari is a coherent account of a philosophy of systems, or specifically a systemic ontology – what they call in *A Thousand Plateaus* a *mechanosphere*.[7] This term signifies nothing less than the cosmos – the whole of reality – thought as a mobile and creative system or 'machine', with the proviso that these terms must be thought outside any mechanistic causality. The link between this work and cybernetics is clear from the very title, which comes from Gregory Bateson who, together with his wife Margaret Mead – both anthropologists – were regular and active participants in the Macy conferences.[8] His repurposing of the term 'plateau' to refer to the moment of an ongoing personal, emotional and sexual intensity in Balinese culture where the mother masturbates her son was repurposed again in Deleuze and Guattari's title, where the to-and-fro of this intensity already hints at their relational ontology.[9] In addition, their link with the theory of complex systems is well known and has been promoted most thoroughly by Manuel DeLanda.[10] If my emphasis is slightly different, this is to highlight Deleuze and Guattari's indebtedness to earlier general systems theory in a manner constructive for the current debate, while wishing to explicitly avoid DeLanda's de-politicised Deleuzian strain of architectural theory, in relation to which, see Eliot Albert's comment on DeLanda's 'de-Marxification' of Deleuze.[11] This de-politicisation is shared with Sanford Kwinter and others, and could be summarised under the banner of a rich architectural formalism of somewhat scientistic bent.[12] To anticipate the argument in relation to architecture: if there is to be an antidote to this hylomorphic schematism in architecture – its continued concern primarily with the form or materiality of those objects we call buildings, a matter not unconnected with its role as a supporter of an unquestioned global capitalism – then this will come via the aforementioned joining of the paths of the humanities and science, rather than by simply translating the methods of common-or-garden science into philosophy or more specifically ontology and architecture – something I believe was very far from the minds of Deleuze and Guattari.

But, on the other hand, I intend to start from the most extreme of scientific and technical thought, namely Claude Shannon's information theory. Poetising science is no more effective than scientistically transforming architecture and philosophy if we wish to understand the common ontology of both. Both need to be examined in their cybernetic and systematic extremes to show how they meet on the current horizon of thought.

Information theory and general systems

> riverrun, past Eve and Adam's, from swerve of shore to bend of bay, brings us by a commodious vicus of recirculation back to Howth Castle and Environs.
>
> Sir Tristram, violer d'amores, fr'over the short sea, had passen-core rearrived from North Amorica on this side the scraggy isthmus of Europe Minor to wielderfight his penisolate war: nor had topsawyer's rocks by the stream Oconee exaggerated themselse to Laurens Country's gorgios while they went doublin their mumper…[13]

So begins James Joyce's *Finnegans Wake*, cited by Shannon as an example of highly redundant English; that is, English where it is difficult to anticipate what the next letter or word will be. In contrast, take an extract from the same author's letter to his lover Nora Barnacle: 'It was you who slid your hand down inside my trousers and pulled my shirt softly aside and touched my prick'.[14] This is written in standard English, which as Shannon points out has lower redundancy: 'the redundancy of ordinary English, not considering statistical structure over greater distances than about eight letters, is roughly 50 per cent.'[15] You can assess this, he explains, by (among other methods) asking someone to fill in unknown letters having removed a random set of 50 per cent of them.[16] In other words, in standard English we only need half the letters to reconstruct the text and get the meaning, whereas in *Finnegans Wake* any removal of letters would prevent us from accurately reconstructing the text. (I make no comment here about the question of reconstructing its meaning.)

Shannon's text is technical. He was essentially the inventor of pulse-code modulation (PCM) and was a researcher at Bell Laboratories. PCM is the method used to code continuous signals such as music, speech, or a visual image into discrete variables by sampling the amplitude of the waves at a given rate and as such forms the basis of all modern communication within the cyber realm (telephone lines, broadband, CD-ROMs, streaming and so on). His article *A Mathematical Theory of Communication* was an attempt – successful – to create a 'modern theory of communication'; its seminal position lies not only in being at the technical original of today's digital communication systems but also in the conceptual work he does on the notion of 'information' and its link to entropy and thermodynamics, specifically the second law thereof whereby entropy in a closed system is held never to reduce.[17] The task of communicating something efficiently over a telephone line – that is, producing information at a receiver – is considered abstractly and in the light of cryptographic theory as a stochastic (that is, random) process of choosing from a set according to the probability of each member of that set, the set in the case of English having an ergodic structure (that is, statistically homogeneous – one area of the text is statistically similar to another) in the form of a Markoff process whereby the chances of one letter depend on the preceding letter (or letters, in the more sophisticated version). Of course, in reality, we don't generally send random information down a telephone line, since that does not help us to communicate; but, perhaps counter-intuitively, an increase in the statistical randomness of a successfully-received message indicates an increase in the measure of information received.

We can see this in the case of Joyce. The quotation from *Finnigans Wake* has low redundancy, which means a statistical analysis shows a high randomness, which in turn means that when it is communicated a lot of 'information' is passed on. The letter to Nora, by contrast, has the high redundancy of 50 per cent associated with standard English, which means that it is statistically relatively easy to predict what the next letter or word is going to be. This means that when it is communicated down an information channel, not so much information is passed on.

Information is here being used in a strict technical and statistical sense, not in the way we usually think of information or meaning (unless we are scientists or technicians speaking within our field). We might argue, for instance, that the letter to Nora has more information or meaning in it than *Finnegans Wake*, which we find hard to understand. Or we might argue the opposite – particularly if we were a literary critic – namely that the latter is fuller of poetic meaning than the former. We would certainly question whether *Finnegans Wake* is at all random, in the sense that we understand Joyce having spent decades on the novel, taking the greatest informed care for each word. That discussion is an interesting and potentially aporetic one amenable, for instance, to a deconstructive reading; but is not one

that is relevant to Shannon's purposes. As Hayles points out, Shannon was careful to distinguish his technical terminology and thought from the usual 'subjective' (as he put it) questions of meaning.[18] As he says, 'these semantic aspects of communication are irrelevant to the engineering problem.'[19] That his definition might subsequently be misused – indeed within cybernetics, to a certain extent – to redefine human communication in general in an inappropriately simplistic manner is merely a specific instance of the more general problem of an impatient misapplication of science and technology to broader questions of human life and the cosmos. Architecture has not been immune to this, and the counter-reaction has fathered a significant strand of hermeneutic architectural theory, for instance that of Dalibor Vesely and Alberto Pérez-Gómez, both of whose work is rooted in Edmund Husserl's diagnosis of a crisis of signs in European science and Hans-Georg Gadamer's contrast between the truth of the human sciences and the method of natural science and technology.[20] But insofar as this strand of architectural theory is precisely that – a counter-reaction to an all-too-impatient application of technology to the problems of human science in general – one might ask if it falls into the opposite trap to the rival hylomorphic formalist architectural theory mentioned above; namely, it rejects the possibility of a consilience between scientific method and humanist truth. Instead, this essay takes further the questions that science (in its systematic and informational guises) raises, to a point where they meet those of a philosophy of radical relation, symbiosis and ecology and thus render these traps irrelevant to a theory of architecture informed by such philosophy.

To return to Shannon: *Finnegans Wake* has lower redundancy than standard English and a higher statistical randomness. This means that relatively more information is sent down the channel to the receiver. Shannon proves that if we want to provide a mathematical measure of this information, called 'H' (Greek *eta*), then H has to be a continuous variable; it has to be such that with increasing information of the same probability, there is more uncertainty (a longer message is more uncertain and conveys more information than a shorter one); and if we split the measure H into two measures of H for successive parts of the original message, the former is the weighted sum of the latter.[21] The function that Shannon derives to calculate this measure H (equal to the negative of the sum of the various probabilities, each multiplied by its logarithm) is remarkably shown to be the same function as that of entropy within thermodynamics, specifically Boltzmann's H theorem.[22] Shannon therefore gives the name 'entropy' to the measure of information, a figure that can be made to lie somewhere between 0 (zero information) and 1 (maximum information). This means that the value of entropy is one *minus* the redundancy: since *Finnegans Wake* has a low redundancy (high randomness), this means that the entropy is high and that a lot of information (close to the value 1) is sent down the information channel. Whereas Joyce's letter to Nora has a redundancy of around 50 per cent, meaning that the entropy (measure of information sent) now drops to approximately 0.5.[23]

Why would Shannon have an intuition that the measure of information would be similar to that of entropy in a thermodynamic system? The reason is that he was thinking in terms of the formalism of these systems (information system or thermodynamic system). I am taking the term formalism here in the same way as in, for instance, quantum physics where the word refers to the mathematics of the theory – how things are 'slowed down' to be expressed by mathematical functions.[24] Thermodynamics thinks of closed systems as a set of microstates (for instance, the movement of each molecule of gas within a closed container), the value of each of which has equal probability. These go to make up a given macrostate, the latter providing (by means of measurements of temperature, pressure and so on) a course-grained description of the gas in the box. The informational

equivalent of the microstates are the values that the pieces of information (for example, letters of the English language) can take, and the total useful information measure (macrostate) is obtained in the same way that entropy was obtained, entropy being a (negative) measure of the useful energy in the thermodynamic system. On the other hand, within the thermodynamic system itself, entropy is related to information because the higher the entropy, the more information is needed to specify exactly what state it is in, since high entropy means high randomness and lack of 'order'. Order is here put into scare quotes because this is the scientific definition of order – a definition which does not necessarily coincide with our intuitive ideas of order for reasons that will become clearer below.

This relationship – what Bertalanffy would call an isomorphism – between entropy and information, established in 1949, subsequently became important in the history of both cybernetics and general systems theory. Interestingly they each take a different tack in relation to it.[25] Cybernetics, in the Macy conferences, indeed follows on directly from Shannon (although the seeds were already there in Wiener's work) to consider entropy primarily in an informational sense, since it is the flow of information from one part of a system back to another 'earlier' part which drives the central cybernetic concept of feedback, be it positive feedback – self-reinforcing or a virtuous or vicious circle – or negative feedback, that is, the tendency of a system or subsystem to achieve homeostasis. As Hayles notes, information flow becomes a key issue for cybernetics, and with its second-order reflexive manifestation even more so, leading to an emphasis on formalising humans as 'information-processing entities who are *essentially* similar to intelligent machines'.[26] This in turn generates the broad currents of thought around neural networks and informatics which, having determined the human brain as machinic sometimes go on to claim that a machine in the form of artificial intelligence can mimic and then go beyond what the human brain can achieve. This circular argument is another example of science being too hastily and too abstractly applied; the general systems theorist would ask, instead: has science even begun to model adequately a single neuron? (Answer: no, it is too complex.) And if not, what justifies the reduction of human brain function to that which we can, happenstance, begin to model, namely a network of neurons abstractly considered? This is not to depreciate what artificial intelligence and machine learning can achieve; merely to point to its limitations vis-à-vis the human brain and other living systems.

General systems theory, on the other hand, tended towards the thermodynamic aspects of entropy, and information comes in more indirectly (in the manner outlined later in this essay). This is partly because its background was in biology, whereas cybernetics started from machine control and feedback. If we take Bertalanffy – a biologist – as emblematic of early systems theory, information is not highly emphasised, but the flow of material and energy is, and to that extent he regards living systems as such flows within which feedback is one, but not necessarily the primary, phenomenon. This makes intuitive sense: a biologist, studying problems of how to characterise the organism in the light of early twentieth century debates around finalism and vitalism, and working experimentally with organisms of various scales, would perforce need to take into account issues of respiration, energy flow, input and output of material (food, defecation) in order to think systemically. Bertalanffy's 1940 article *The Organism Considered as a Physical System* already makes these points, and characterises the organism as an open system with a through-put of energy and material such that, in contrast to the second law of thermodynamics, the entropy is decreased and the organism is, or rather becomes, more and more finely ordered.[27] Organisms are essentially negentropy machines: machines for holding off entropy, increasing order by taking energy and matter from their environment. Ilya Prigogine will later clarify this activity as

that of a dissipative structure, whereby the negentropy within the structure (the organism) is balanced by an increase of entropy which it discharges (by means of waste, and so on) into the environment.[28] The fact that living systems are open systems is a truism today, but Bertalanffy was revolutionary, since science up to that point had almost exclusively theorised closed systems within a mechanistic framework. He was therefore calling for a different approach to the nature of the reality considered by science, a matter that extended beyond biology into broader ontological and epistemological issues. As he points out, it was still possible in 1948 for analytical philosophy, in the person of Bertrand Russell, to dismiss the importance of systematic thinking, that is, thinking that considered the place of parts within a whole. Russell considered, on the contrary, that all thought should proceed by the method of analysis – that is, the taking apart of things and the consideration of their parts; and that all knowledge, scientific or not, was to be obtained and could be obtained by this essentially Aristotelean method.[29]

Hyper-relational general systems theory

General systems theory, established by Bertalanffy in the 1940s, reaches its apogee in the 1970s, a high-point well expressed by the publication of the monumental volume *Living Systems* by James Grier Miller.[30] This is essential reading for any historian of systems theory; rigorous in both content and form, inspired partly by his initial training in philosophy with Alfred North Whitehead (whose *Process and Reality* would, on a longer account, be tied into our story), it sets out to describe the whole organosphere, from the basic unit of the cell through six further vertical levels of organ, organism, group, organisation, community, society and supranational system.[31] The introduction to *Living Systems* gives perhaps the best available summary of general systems theory, within which it characterises cybernetics as a (fairly small) component.[32] The book represents a vertical deepening and generalising of systems theory, and takes cybernetics as a part of that broader theory largely because it now considers the whole gamut of systems within life and cements ecological thinking as a key component of our modern age. On the horizontal axis, similarly, Bertalanffy in the 1950s and 1960s was already widening the scope of systems thinking to become what he saw as a truly general theory, covering many aspects of reality including culture and the human sciences. In that sense he saw Russell's analytical thinking as a subset of general systems theory: analysis can occur within systems thinking, but systems thinking cannot be circumscribed by mere analysis.

In a series of essays collected in *General System Theory*, Bertalanffy outlines and justifies this broadening of scope. He shows the limitations of 'the analytic, mechanistic, one-way-causal paradigm of classic science' by proposing a new paradigm – a 'theory of "systems" in the various sciences (e.g. physics, biology, psychology, social sciences)'.[33] As well as making vertical links to dynamic ecology and the ethology of Jacob von Uexküll (particularly relevant to the connection I will make with Deleuze and Guattari below), establishing or clarifying critical notions such as equifinality, isomorphism and emergence, arguing against analogies and metaphors ('analogies are scientifically worthless') in science and promoting systemic explanations and models, he makes the vital step of considering the epistemological issues involved.[34] It is worthwhile quoting his comments on this issue at some length:

> The epistemology (and metaphysics) of logical positivism or empiricism was determined by the ideas of physicalism, atomism, and the 'camera-theory' of knowledge [i.e. a naïve realist view of knowledge]. These, in view of present-day knowledge, are obsolete … simple 'reduction' to the elementary particles and conventional laws of physics does not appear feasible. Compared to the analytical procedure of classical science with resolution into component elements and one-way or linear causality as basic category [sic.], the investigation of organized wholes of many variables

> requires new categories of interaction, transaction, organization, teleology etc. … Furthermore, perception is not a reflection of 'real things' (whatever their metaphysical status) and knowledge is not a simple approximation to 'truth' or 'reality'. It is an interaction between knower and known… Physics itself tells us that there are no ultimate entities like corpuscles or waves, existing independent of the observer.[35]

It seems to me that this extract, from the 1971 British edition foreword, is remarkable in drawing out some lessons from general systems theory that have yet to make their way through science, let alone other fields of knowledge. An example: when considering how a respiratory virus operates, science still rarely takes a dynamic systems approach. One hears analogies such as that the lungs are like a sponge; but already in a 1969 paper Bertalanffy was pointing out that the pulmonary alveolar cells in the lung have an average renewal time of only six days; in this context the fact that viruses destroy lung cells becomes, evidently, a dynamic systems issue requiring complex explanation, not static analogies; in turn, clearly the action of a virus has to be seen as taking on and working as a significant part of much broader systems than the lungs, such as (upwards) cultural, transport, social and political systems and (sideways) the immune system, temperature control system and hormone systems of the body. The question is systemic and ecological from top to bottom and all the way across, in a manner which Bertalanffy would already recognise in the 1960s. Despite this, however, and aside from a few researchers such as David Pouvreau, his work is now largely ignored, and his influence unrecognised.[36]

I believe we can summarise Bertalanffy's thought as essentially hyper-relational. On the one hand we can see this hyper-relationality in those philosophers who, likewise – and likewise influenced by Whitehead's process philosophy – take relations as the foundation of ontology and an associated and intermixed epistemology.[37] On the other hand, the fate of general systems theory is to have become, in scientific terms and despite the provisos I raise above, almost de rigueur; one only has to think, for instance, of genetics and epigenetics, where research focuses on understanding and intervening in the extraordinarily complex interactive machines operating at lightning speed – that is, systems – making up our cells' reproductive apparatus.[38] Incidentally, here is an instance where the use of the shortcut metaphorical language of 'reading', 'copying', 'alphabet' and so on of DNA can sometimes obscure clarity, as Bertalanffy would note. DNA is not read, there is no copying, there is no alphabet; what there are are little machines, doing what machines do… More pertinently for our purposes, in the field of quantum physics all serious thinking is now systematic and highly relational; this systemic thinking derives partly from the earlier more limited notions of closed thermodynamic and other systems, but is informed as we will see by a similar hyper-relational thought to that of Bertalanffy.

Hyper-relational philosophy

To address the first of these points, as previously intimated it is in the work of Deleuze and Guattari that we see most evidence of this hyper-relational thought in philosophy.[39] In *A Thousand Plateaus* and elsewhere, they frame the real as having the character of an 'assemblage' or a 'machine'.[40] These, in essence, are systems – but a particular type of system consonant with Bertalanffy, which moves on from the static qualities of structuralism (which Deleuze aligned himself with somewhat in the 1960s) and, perhaps under the influence of Guattari, takes on a mobile and dynamic aspect.[41] In that regard, they appropriate Bergson's notion of becoming and raise it to a central place in their philosophy: nothing *is*, everything is *becoming* or *in becoming* at the same time as constantly being in relation to other things.[42] Deleuze had already established the primacy of difference in his earlier book *Difference and Repetition*; what he means by this is that identity is derived from – an epiphenomenon

of – difference, and not the other way around, as philosophy and thought had almost always framed it.[43] To place difference first, at the basis of things, is to privilege relations and the interplay of being – precisely a hyper-relationality. This is a Nietzschean theme, since Deleuze sees in Nietzsche the one who frames the world as the interplay of forces, and when he says 'the eternal return of the same' he means, for Deleuze, not the return of the same thing, but that 'the same' (and being) is said of that which eternally returns.[44] Being is said of – derived from – becoming, not vice versa.[45] In this, Deleuze interplays with the early work of Jacques Derrida and in particular his new concept (as Deleuze says) of *différance*.[46] *Différance* means the differential origin of difference – a concept which Deleuze picks up on in *Difference and Repetition.*[47] Deleuze quotes Derrida at some length, from *Writing and Difference*, including the following: 'To say that *différance* is originary is simultaneously to erase the myth of a present origin.'[48] The erasure of a present origin is precisely the erasure of being in favour of *différance* or becoming; again, a hyper-relationality, posited as the basis for a new, Nietzsche-inspired philosophy.

Perhaps the clearest exposition of the extreme relational quality of this philosophy is contained in Deleuze's notion of the fold. Contrary to certain simplistic architectural interpretations of this concept, what Deleuze asks us to think in relation to the Baroque and Leibniz in his book *The Fold* is Leibniz's notion that reality consists of folds to infinity. 'The Baroque fold unfurls all the way to infinity' and 'a fold is always folded within a fold, like a cavern in a cavern.'[49] This statement is to be taken literally, which means that it is the fold which comes first (*différance* at the origin); folding produces the material which is folded, as an after-effect, as an epiphenomenon of the fold. As Deleuze says elsewhere: relations are external to their terms.[50] It is relations (that is, the fold) that come first; they retrospectively 'make' the terms between which the relations occur, a theme taken up from Gilbert Simondon's idea of transduction which, as Bernard Stiegler glosses it (virtually quoting Deleuze), is 'a relation which constitutes its terms'.[51]

There is therefore a strong conceptual likeness between the generality and priority of relations in Bertalanffy's general systems theory and the prioritising of transductive relations and difference in the post-Nietzschean philosophy of Derrida, Deleuze and Guattari.[52] In the case of Deleuze and Guattari, there are some more specific common interests. One of these I have already mentioned: Bertalanffy's use of the ethological theory of Jakob von Uexküll, specifically reference to the latter's book *A Foray into the Worlds of Animals and Humans*.[53] Bertalanffy's 1955 summary of this theory, particularly the invocation of Uexküll's famous ethology/ecology of the tick, could be taken directly from Deleuze and Guattari's later reference in *A Thousand Plateaus*:

> Take, for instance, a tick lurking in the bushes for a passing mammal in whose skin it settles and drinks itself full of blood. The signal is the odor of butyric acid, flowing from the dermal glands of all mammals. Following this stimulus, it plunges down; if it fell on a warm body – as monitored by its sensitive thermal sense – it has reached its prey, a warm-blooded animal, and only needs to find, aided by tactile sense, a hair-free place to pierce in.[54]

A further conceptual link is the aversion to metaphor and analogies on the part of Bertalanffy in relation to scientific explanations: as noted above, he regards them as useless. In fact, this follows, logically, from his hyper-relationality: metaphor assumes that there is indeed an original 'natural' meaning of words which metaphor can then translate into other contexts.[55] The relational take is to disavow this belief and wager instead for the interplay from the outset of supposed original and supposed derived meanings. This aversion he shares with Deleuze, who from beginning to end of his philosophy avoids the metaphorical use of words, for the same reason.[56]

Hyper-relational science

I turn now to the second point, that of the current position of science at its relational extreme – namely, how quantum physics is being conceptualised by those scientists most attuned to the transductive question of hyper-relationality.[57] We return here also to the key topic of information, in its relational aspect, because it is fair to say that the concept of information is now the driver of cutting-edge quantum mechanics, both in its theoretical manifestations and the practical realm of quantum computing.

Again, here, we have to be careful about the use of the word 'information'. In quantum physics it is used in a specific sense, deriving indeed from Shannon's 1949 seminal paper. Seminal, it turns out, not only in establishing the practical basis of our modern cyber technologies, but also in establishing a theoretical framework that extends well beyond those practical issues. The most succinct exposition of quantum information is available in Carlo Rovelli's essay, available online, on relative information, which is brief and accessible enough for me to recommend that the reader glance quickly through it before proceeding. Rovelli is one of the most eminent quantum physicists working in the field, and his expositions have the benefit of both attempting to drill down to the broadest implications of quantum theory, and expressing these in intuitive language. He outlines the concept of relative information as a scientific notion distinct from meaning. This concept is 'just physical', he says. He states:

> In nature, variables are not independent; for instance, in any magnet, the two ends have opposite polarities. Knowing one amounts to knowing the other. So we can say that each end 'has information' about the other. There is nothing mental in this; it is just a way of saying that there is a necessary relation between the polarities of the two ends. We say that there is 'relative information' between two systems anytime the state of one is constrained by the state of the other. In this precise sense, physical systems may be said to have information about one another, with no need for a mind to play any role.[58]

The exposition here is beautiful, as quantum physics can be, but we need to look at two more technical articles from the same author to unwind the concepts, make the connection with entropy, and reveal the full hyper-relationality of this thinking. Rovelli's 2013 article on the topic starts by questioning the notion of entropy.[59] As previously noted, the second law of thermodynamics states that, in a closed system, entropy always increases. This makes it sound as though entropy is some absolute quality, and indeed many interpret this law to say that the universe will, eventually, die a heat death as entropy increases to the limit. This, however, is to assume something that we cannot know, namely that the universe is indeed a closed system (incidentally this notion of thermodynamic heat death is something Nietzsche had already critiqued in the late nineteenth century, as Deleuze notes).[60] What Rovelli points out is that entropy is always relative to the relevant functions of the system being investigated, that the laws of thermodynamics deal with the relative coupling of two systems, and that entropy is indeed information, as per Shannon, since it is defined as 'the number of microstates compatible with a given macrostate' – a definition that accords with our discussions above. Here is the hyper-relationality: 'the information relevant in physics is always the *relative* information between *two* systems.' He gives this fact a poetic bent: 'it is not the microstate of the Sun which is hot, it is the manner in which the Sun affects the Earth which is *objectively* hot.'[61] We could say here that what Rovelli is doing is reframing objectivity – or, the notion of the absolute – in terms of relationality. The absolute, or that which is objective, is an epiphenomenon of the relative.

Thus entropy and information are always relative. If we break a cup by dropping it onto the floor, there is usually thought to be an increase in entropy – that is, an increase in disorder – but this depends,

Rovelli says, on the position of the observer: it is possible to conceive of a situation where the cup breaking on the floor, if the pieces land on an image of those pieces visible to a certain observer, increases order rather than decreases it.[62]

Rovelli has bigger fish to fry. In his 2008 article *Relational Quantum Mechanics*, this concept of relative information allows the derivation of quantum physics from the same hyper-relative ground. What Rovelli proves is that in quantum terms, 'different observers give different accounts of the same sequence of events.'[63] What this means, in general systems terms, is that quantum physics deals with the broadest of all systems, where the system includes the 'observer'.[64] There is no escaping the system, and the results of any quantum experiment depend on the way that an experiment is set up – as the famous example of the double slit experiment invariably shows.[65] For quantum physics, there is no pre-existing real condition that the foundational experiments reveal; rather, these experiments *create* that condition that we subsequently take for real.[66]

Rovelli is one of a group of quantum physicists who are willing to accept this transductive hyper-relationality; others include Christopher Fuchs, Wojciech Hubert Zurek and N. David Mermin's so-called Ithaca interpretation of quantum mechanics.[67] What their views imply is a rejection of a naïve realist ontology of the world – that is, the 'camera' notion of our relationship to the world that somehow our perceptions are of some pre-existing absolute reality. Rather, we are systemically intertwined within reality, such that the intertwining and interrelations create that reality.[68] There are many quantum scientists who still take the naïve realist view, and the supposed 'weirdness' of quantum physics derives entirely from our habit of – consciously or unconsciously – remaining wedded to it. This can be seen in many of the competing interpretations of quantum physics, such as the many-worlds theory, or the hidden variables theory; these are basically ways of 'saving the object', of not allowing relationality to run all the way down. Whole books have been written bewailing the unacceptable state of quantum physics as violating basic common sense.[69] What Rovelli does is to re-write this common sense.

Nonetheless, in his account there remains the residual metaphor of the term 'information'. However deep our understanding of Shannon, and however much we accept the necessary abstraction made in the scientific definition of this word, it does not denote precisely enough what Rovelli is referring to. When he says, for instance, that

> the light that arrives at our eyes carries information about the objects which it has played across; the color of the sea has information on the color of the sky above it; a cell has information about the virus attacking it

this remains open to the critique of Bertalanffy and Deleuze that 'information' here is an analogy or metaphor, and is being used in two very different instances.[70] There is too much humanity in this term – humanity which needs to be expunged entirely in order to secure the thought that this is not to do with a limitation of our supposed subjectivity, but is to do with the very structure of the world. This, in turn, prevents Rovelli from taking the final step and allowing relation to take precedence; in the end, he wagers for the existence of those elementary objects which Bertalanffy had already warned us against in 1971; he remains wedded to Democritus's notion of the atom (about whom he has written a book) instead of Heraclitus's notion of flow – the latter a notion shared, of course, with Deleuze and Guattari. Rovelli says that information is 'the infinite game of mirrors reflecting one another formed [sic] the correlations among the structures made by *the elementary objects*.'[71] In other words, the 'elementary objects' remain part of his theory, which is why 'information' remains the word that he chooses to use. And this despite quoting Zurek on the relative non-existence of 'properties themselves':

'correlations between the properties of quantum systems are more basic than the properties themselves'.[72] Zurek is explicit about what this means: 'This order of importance, in which a correlation – a record of a property – comes before the property, reverses the ordinary hierarchy to which one is accustomed within the realm of everyday experience', in other words, is counter to the naïve realist viewpoint which places entities (being) before relations (becoming).[73]

Why take this final step? Why dispose, in the end (or at the beginning) of any notion of the common-sense object, of the entity, of the 'elementary object' or the Democritian atom? This seems to me to be simply a question of utilising Occam's razor: do not multiply explanations! Rovelli, and others, have shown that we cannot do without a notion of relation; Deleuze and Bertalanffy give us the hyper-relationality of a general systems theory and a philosophy of the assemblage (mobile, dynamic system). Quantum physics itself – the most accurate of scientific theories – shows us that it is the relations between things that give rise to the phenomena that are then called, for convenience's sake, 'particles'. The particle-quality of these supposed elementary particles does not exist; they occur as epiphenomena of the relations which occur in relational systems. The term that should therefore be used to replace 'information' describes more precisely what is being said: it is simply the word 'relation' itself. When Rovelli describes the interplay between the light of the sky and colour of the sea he is not talking about information so much as about the relations between these things.

This is the final and most pertinent conceptual link I wish to make in this article, in order to draw the conclusion that we are now at a stage where we can not only envisage but also deploy a common relational conceptuality across philosophy and science, and with that, across the whole of human endeavour both practical and theoretical.

Conclusion

Taking this hyper-relational step explains, for instance, why mathematics is so successful in explaining the world scientifically. Such success is puzzling if the world is made of entities. By what right would an entity enter into relations such that they accord with mathematics? But the problem disappears if the world is essentially transductive, made of pure relations. For what is mathematics other than the science and art of pure relations? If entities are an epiphenomenon of relations, which are more 'basic' than them, then the 'correlation' between maths and nature becomes self-evident.

Similarly, what is the relation between the mind and the brain, that is, between consciousness and the physical reality of our embodied brain? There remain endless debates around this so-called hard question of consciousness.[74] But the problem, again, disappears if we regard the physical brain as a transductive epiphenomenon of relations, since what the mind is, is nothing other than the ability (conscious and unconscious) to spin, endlessly, relations among themselves.[75] Spinoza says: the mind and the body are the same thing.[76] Perhaps we are getting to the point where we can understand the profundity of this statement.

What, then, is the relevance of this journey for architecture, as a taught, professional and creative discipline? I have shown that the relations inherent in systems and ecological thinking go all the way down, and all the way across. There is no scope for a naïve realist interpretation of reality in general: that ontology is defunct. But physicists and stubborn realist philosophers are not the only ones to revert to it. Architects, and the discipline of architecture, remains wedded to such a realist interpretation of things, perhaps because we spend too much time with large objects that we call buildings. But the buildings are mere epiphenomena of broader political, interpersonal, ecological and essentially relational matters, assemblages, systems and interplays.

This might mean something quite simple in practice: a slight shift. As one cybernetic architect

– Cedric Price – said to a potential client: 'you do not need a house, you need a divorce'.[77] What Price meant was this: your relations, the symbiotic ecosystem within which you relate to your wife, is in a certain state. Do not expect a mere object to rectify it! I, as an architect and cyberneticist, will not play the game of reducing the issues to objective ones. Let's work with, intervene in, and (over-) turn the system, the set of relations, even at the expense of not building anything.

Notes

1. See C.P. Snow, 'The Two Cultures', *Leonardo* 23, no. 2/3, *New Foundations: Classroom Lessons in Art/ Science/Technology for the 1990s* (1990): 169–73. Reprinted from 'The Rede Lecture, 1959' in C. P. Snow, *The Two Cultures: And a Second Look*, (Cambridge: Cambridge University Press, 1959, 1964), 1–21. That the key difference between the two cultures was, in 1950s UK, seen to be a non-familiarity on the one hand with the second law of thermodynamics and on the other the poetic work of Shakespeare is pertinent to the topic at hand.
2. Taking the term 'strata' from Deleuze and Guattari. See Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, trans, Brian Massumi (Minneapolis: University of Minnesota Press, 1987), 39–74, in the chapter/plateau '10 000 BC: The Geology of Morals (Who Does the Earth Think It Is?)'.
3. John Bruni, 'Expanding the Self-Referential Paradox: The Macy Conferences and the Second Wave of Cybernetic Thinking', 78–83 in *Traditions of Systems Theory: Major Figures and Contemporary Developments*, ed. Darrell P. Arnold (New York/ Abingdon: Routledge, 2014). Bruni is quoting from page 7 of a useful book by Katherine Hayles which emphasises cybernetics as 'a theory of communication *and control* [my emphasis] applying equally to animals, humans, and machines': N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999), 7. As I indicate below, I have doubts about this 'control' or 'governorship' aspect of cybernetics; not that control as such is a bad thing seen in a broader scope – more that if taken as the essence, or the beginning not only historically but also ideally, of cybernetics/systems theory, then the more creative aspects of systems thought which Deleuze and Guattari emphasise ('the production of the new') potentially gets covered over in the name of some form of determinism.
4. Where he states:

   > The Macy thematic statement uses the word 'system'. Around the time that cybernetics was reborn (1946), the first article specifically on general systems theory was published by the biologist Ludwig von Bertalanffy. He claimed to have developed this theory in lectures starting in 1937. Simplistically stated, Bertalanffy's general systems theory was the base that spawned the assorted variety of systems sciences that we have now. Cyberneticians and systemists have always understood that there was a connection between their two fields. Some see the terms as synonyms … People such as Gordon Pask insisted they didn't care what name was used.

   Ranulph Glanville, 'Cybernetics: Thinking Through the Technology', 45–77 in *Traditions of Systems Theory*, 46. Disclosure: Glanville taught the present author.
5. Becker and Broder Breckling, 'Border Zone Between Ecology and Systems Theory', 385–403 in *Ecology Revisited,* ed. Astrid Schwarz and Kurt Jax (Dordrecht: Springer, 2011), 388.
6. Left out of the account here for reasons of space is the tektology of Aleksandr Bogdanov dating from the second decade of the twentieth century, which, as environmental philosopher Arran Gare has argued (in 'Aleksandr Bogdanov and Systems Theory', *Democracy and Nature* 6, no. 3 (2000): 341) predates and probably influenced Bertallanfy's general systems theory. Tektology is the 'new science of organisation' invented by Bogdanov, a process-philosophy entirely consonant with the hyper-relationality I argue for in this essay. See, among other writings by Bogdanov,

The Universal Science of Organization (Tektologia) from 1913, reprinted as *Bogdanov's Tektology*, trans. not acknowledged (Hull: Centre for Systems Studies, 1996) and *Essays in Tektology*, trans. George Gorelik (Seaside, CA: Intersystems Publications, 1980). Arran Gare's work on philosophical ecology could also be woven constructively into this story and, of course, related to architecture. See Arran Gare, *Philosophical Foundations of Ecological Civilization: A Manifesto for the Future* (London: Routledge, 2016); 'From "Sustainable Development" To "Ecological Civilization": Winning The War For Survival', *Cosmos and History: The Journal of Natural and Social Philosophy* 13, no. 3 (2017): 130–53; and, again pertinently for architecture, 'Architecture and the Global Ecological Crisis: From Heidegger to Christopher Alexander', *The Structurist: Toward an Ecological Ethos in Art and Architecture* no. 43/44 (2003/2004): 30–37. I am grateful to Dulmini Perera for the reference to Bogdanov.

7. This is the last word of *A Thousand Plateaus*. Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, trans. Brian Massumi (Minneapolis: University of Minnesota Press, 1987), 514.
8. For an account, see Samuel Gerald Collins, 'Do Cyborgs Dream of Electronic Rats? The Macy Conferences and the Emergence of Hybrid Multi-Agent Systems', AAAI Fall 2007 Symposium, https://www.aaai.org/Papers/Symposia/Fall/2007/FS-07-04/FS07-04-005.pdf. Collins points to Bateson and Mead's central role in establishing second-order cybernetics – that is, the inclusion of the observer within the paradigm: 'One of the enduring legacies of the Macy Conferences was the question of the observer, the role of self-reflexivity in the cybernetic circuit.' Ibid., 26.
9. Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* (London and Northvale NJ: Jason Aronson Inc., 1987 (1972)), 121. The reference is explained in *A Thousand Plateaus* on pages 21 and 22 and note 20 on page 520 (where the page number is wrongly given as 113). It is worthwhile quoting from Bateson here: 'Typically, the mother will start a small flirtation with the child, pulling its penis or otherwise stimulating it to interpersonal activity. This will excite the child, and for a few moments cumulative interaction will occur. Then just as the child, approaching some small climax, flings its arms around the mother's neck, her attention wanders.'
10. See Manuel DeLanda, *Intensive Science and Virtual Philosophy* (London and New York: Bloomsbury Academic, 2013 (2002)); Manuel DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity* (London and New York: Continuum, 2006); and more specifically in relation to architecture Manuel DeLanda, 'Deleuze and the Use of the Genetic Algorithm in Architecture', in *Architectural Design* 72, no. 1 (January 2002): 9–12 and Manuel De Landa, 'Deleuze, Diagrams and the Genesis of Form', in *Amerikastudien/American Studies* 45, no. 1, *Chaos/Control: Complexity* (2000): 33–41.
11. Eliot Albert, 'A Thousand Marxes', in *Mute* 1, no. 11 (Autumn 1998). Available at www.metamute.org/editorial/articles/thousand-marxes. I have written in more detail about this elsewhere: see Tim Gough, 'Flows of Capitalism, Flows of Architecture', *Ardeth* no. 03 (Fall 2018 – *Money*): 97–114.
12. Whose seminal *Architectures of Time* cast Deleuze as a scientistic formalist whose interest in, for instance, the political and minoritarian side of Kafka was merely a result of the supposedly baleful (i.e. political) influence of Guattari. Sanford Kwinter, *Architectures of Time* (Cambridge, MA: MIT Press, 2001), 115. See also Kwinter's short but essential piece 'Who's Afraid of Formalism?' in among other places Foreign Office Architects' *Phylogenesis*. Sanford Kwinter, 'Who's Afraid of Formalism?' in Foreign Office Architects, *Phylogenesis: FOA's Ark* (Barcelona: Actar, 2003), 96–100. Reprinted from *Any Magazine* no. 7/8. That Kwinter remains tied to a hylomorphic way of characterising architecture needs some justification: in 'Who's Afraid of Formalism' he makes specific reference to Aristotle's formal causes – clearly within the hylomorphic tradition – and where he says in the same piece that 'the manifest form – that which appears

– is the result of a computational interaction between internal rules and external (morphogenetic) pressures that, themselves, originate in other adjacent forms', this , while no doubt a *rich* formalism informed by Gilbert Simondon, remains nonetheless a question of the *form* of something realised in a *material* (as in the work of Simondon himself).

13. James Joyce, *Finnegans Wake* (London/Boston: Faber and Faber, 1975 [1939]), 3.
14. James Joyce, letter to Nora Barnacle, 3 December 1909: 44 Fontenoy Street, Dublin. Quoted in Nadja Spiegelman, 'James Joyce's Love Letters to His "Dirty Little Fuckbird"', *The Paris Review* blog, 2 February 2018, https://www.theparisreview.org/blog/2018/02/02/james-joyces-love-letters-dirty-little-fuckbird/.
15. C.E. Shannon, 'A Mathematical Theory of Communication', in *The Bell System Technical Journal* 27 (July 1948): 379–423, (October 1948): 623–56; 393.
16. Ibid., 394.
17. Ibid., 379.
18. Hayles, *How We Became Posthuman*, 19.
19. Shannon, 'Mathematical Theory of Communication', 379.
20. Dalibor Vesely, *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production* (Cambridge, MA: MIT Press, 2004); Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science* (Cambridge, MA: MIT Press, 1983); Edmund Husserl, *The Crisis of European Sciences and Transcendental Phenomenology*, trans. David Carr (Evanston: Northwestern University Press, 1970); Hans-Georg Gadamer, *Truth and Method*, trans. William Glen-Doepel (London: Sheed and Ward Stagbooks, 1975 [1960]).
21. Shannon, 'Mathematical Theory of Communication', 389. The last condition (the weighted sum) is hard to explain in words; the reader should refer to Shannon's paper where a clear graphical explanation is given.
22. Ibid., 390.
23. Strictly the *relative* entropy. Ibid., 394.
24. In Deleuze and Guattari's *What is Philosophy?* the relation between art, philosophy and science is clarified as that whose object is the function; and in order to relate a function to reality there is in science a sort of 'slowing down' which actualises matter and allows mathematics to gain a hold. Gilles Deleuze and Félix Guattari, *What is Philosophy?*, trans. Graham Burchell and Hugh Thomlinson (London/New York: Verso, 1994), 118.
25. Ludwig von Bertalanffy, *General System Theory* (Harmondsworth: Penguin Books, 1973 [1968]), 20.
26. Hayles, *How We Became Posthuman*, 7. In relation to information flow, see page 51 and Chapter 3 of the same book.
27. Ludwig von Bertalanffy, 'The Organism Considered as a Physical System', 127–145 in *General System Theory*, 128. On the open system question, see more specifically Ludwig von Bertalanffy, 'The Model of Open System', 146–62 in *General System Theory*.
28. Ilya Prigogine, *Time, Structure and Fluctuations*, Nobel Lecture, 8 December 1977.
29. Bertalanffy, *General System Theory*, 67. The Russell reference is to Bertrand Russell, *Human Knowledge, its Scope and Limits* (London: Allen and Unwin, 1948). The Aristotle reference is to Book 1 of *Physics* where the task of knowledge is given as an analytical method proceeding from whole to part. Aristotle, *Physics*, trans. C.D.C Reeve (Indianapolis/Cambridge: Hackett, 2018), 2.
30. James Grier Miller, *Living Systems* (New York: McGraw-Hill, 1978).
31. Ibid., xxvii. In relation to Whitehead, see Alfred North Whitehead, *Process and Reality: An Essay in Cosmology*, ed. David Ray Griffin and Donald W. Sherburne (New York: Free Press 1978).
32. Ibid., 36: 'Cybernetics, the study of methods of feed-back control, is an important part of systems theory.'
33. Bertalanffy, *General System Theory*, xix and xvii. (Foreword to the British edition).
34. Ibid., 109, 240–45, 39, 33, 80–88, 54 and 85 .
35. Ibid., xx–xxi. (Foreword to the British edition). My emphasis.
36. See, among other publications, Pouvreau's PhD thesis, his essay in the Arnold volume, and, with Manfred Drack, their history of Ludwig von Bertalanffy, Parts

1-3. David Pouveau, 'The Hermeneutical System of General Systemology: Bertalanffian and Other Early Contributions to Its Foundations and Development', 84–136 in *Traditions of Systems Theory*; David Pouveau and Manfred Drack, 'On the History of Ludwig von Bertalanffy's "General Systemology", and on its Relationship to Cybernetics', *International Journal of General Systems* 36, no. 3 (June 2007): 281–337 Part 2 in vol. 43, no. 2 (2014): 172–245; Part 3 in vol. 44, no. 5 (2015): 523–71.

37. As Bertalanffy was: see Bertalanffy, *General System Theory*, 10 and 46.
38. For a good summary, see Nessa Carey, *The Epigenetics Revolution*: *How Modern Biology is Rewriting Our Understanding of Genetics, Disease and Inheritance* (London: Icon Books, 2011).
39. Of course, elsewhere too, for instance in all post-humanisms; in Bernard Stiegler's organology (similar in intent to Deleuze and Guattari's mechanosphere); in Gilbert Simondon's thought of the transductive relation; in Foucault, Klossowski and Blanchot; in fact in all who take Nietzsche seriously.
40. Deleuze and Guattari, *A Thousand Plateaus*, 4, 79, 554–56.
41. This development and influence can be seen, for instance, in the changes that occur to the various editions of Deleuze's *Proust and Signs*, whereby the later editions become markedly more machinic, more concerned with the assemblage. Gilles Deleuze, *Proust and Signs,* trans. Richard Howard (London: the Athlone Press, 2000 [1964]). On Deleuze's relation to structuralism, see Gilles Deleuze, 'How Do We Recognise Structuralism?', in *Desert Islands and Other Texts 1953–1974*, trans. Melissa McMahon and Charles J. Stivale (Los Angeles/New York: Semiotext(e), 2004), 170–92.
42. Deleuze and Guattari, *A Thousand Plateaus*, 337.
43. Gilles Deleuze, *Difference and Repetition*, trans. Paul Patton (London, The Athlone Press, 1994 [1968]), in particular pages 26–27 but also scattered throughout.
44. Gilles Deleuze, *Nietzsche and Philosophy*, trans. Hugh Tomlinson (London: The Athlone Press, 1983 [1962]), 39–40. Also page 48: 'We misinterpret the expression "eternal return" if we understand it as "return of the same". It is not being that returns but rather the returning itself that constitutes being insofar as it is affirmed of becoming and of that which passes. It is not some one thing which returns but rather returning itself is the one thing which is affirmed of diversity or multiplicity.'
45. Deleuze, *Difference and Repetition*, 40.
46. Gilles Deleuze, 'We Invented the Ritornello', in *Two Regimes of Madness: Texts and Interviews 1975–1995*, trans. Ames Hodges and Michael Taormina (Los Angeles/New York: Semiotext(e), 2006), 377–81, 381.
47. Deleuze, *Difference and Repetition*, 318.
48. Jacques Derrida, 'Freud and the Scene of Writing', in *Writing and Difference*, trans. Alan Bass (London: Routledge & Kegan Paul, 1978), 255.
49. Gilles Deleuze, *The Fold: Leibniz and the Baroque*, trans. Tom Conley (London: The Athlone Press, 1993), 3 and 6.
50. Gilles Deleuze and Claire Parnet, *Dialogues II*, trans. Hugh Tomlinson, Barbara Habberjam and Eliot Ross Albert (London/New York: Continuum, 2006), 41.
51. Bernard Stiegler, 'Deconstruction and Technology: Fidelity at the Limits of Deconstruction and the Prosthesis of Faith', trans. Richard Beardsworth, in *Jacques Derrida and the Humanities: A Critical Reader*, ed. Tom Cohen (Cambridge: Cambridge University Press, 2001), 250.
52. Reference could also be made to hyper-relationality in the non-continental tradition of philosophy, and in particular to James Ladyman's (and associated philosophers') ontic structural realism. This posits that 'relational structure is more ontologically fundamental then objects', in *Every Thing Must Go: Metaphysics Naturalised* by James Ladyman and Don Ross (Oxford: Oxford University Press, 2007), 145. Ladyman precisely uses quantum theory to support his position. For a recent summary see Laura Candiotto, 'The Reality of Relations', *Giornale di Metafisica* 2 (2017): 537–51. Space does not permit here what would be an interesting analysis of the relations between this strand of relational philosophy and that of the post-Nietzschians in the continental tradition, not

least the passage via Ernst Cassirer's structuralism of the 1930s; see Ernst Cassirer, *Determinism and Indeterminism in Modern Physics* (New Haven: Yale University Press, 1936[1956]).

53. Jacob von Uexküll, *A Foray Into the Worlds of Animals and Humans With a Theory of Meaning*, trans. Joseph D. O'Neil (Minneapolis: University of Minnesota Press, 2010).
54. Bertalanffy, *General System Theory*, 241. The equivalent passage from *A Thousand Plateaus* reads: 'For example, the Tick, attracted by the light, hoists itself up to the tip of a branch; it is sensitive to the smell of mammals, and lets itself fall when one passes beneath the branch; it digs into its skin, at the least hairy place it can find. Just three affects…', 257.
55. As Derrida points out in his essay *Qual Quelle*: Jacques Derrida, 'Qual Quelle', in *Margins of Philosophy*, trans. Alan Bass (Brighton: The Harvester Press, 1982), 273–306.
56. See Daniel W. Smith, 'Sense and Literality: Why There Are No Metaphors in Deleuze's Philosophy', in *Deleuze and Guattari's Philosophy of Freedom: Freedom's Refrains*, ed. Dorothea Olkowski and Eftichis Pirovolakis (Edinburgh: Edinburgh University Press, 2019), 45–67.
57. The link between Deleuze's thought and quantum theory has been made by, for instance, Wim A. Christiaens in 'The Deleuzian Concept of Structure and Quantum Mechanics', in *Probing the Meaning of Quantum Mechanics: Physical, Philosophical, and Logical Perspectives*, ed. Aerts Diederik et al. (Singapore: World Scientific Publishing, 2014), 189–208.
58. Carlo Rovelli, 'Relative Information', *Edge.org* (2017), www.edge.org/response-detail/27074.
59. Carlo Rovelli, 'Relative Information at the Foundation of Physics', in *It from Bit or Bit from It? On Physics and Information*, ed. Anthony Aguirre, Brendan Foster and Zeeya Merali (Berlin: Springer, 2015), 79–86, https://arxiv.org/abs/1311.0054.
60. 'Nietzsche's account of the eternal return presupposes a critique of the terminal or equilibrium state . Nietzsche says that if the universe had an equilibrium position, if becoming had an end or final state, it would already have been attained.' Deleuze, *Nietzsche and Philosophy*, 47.
61. Carlo Rovelli, 'Relative Information at the Foundation of Physics', 1; my emphasis.
62. Ibid., 2.
63. Carlo Rovelli, 'Relational Quantum Mechanics', *International Journal of Theoretical Physics* 25 no. 8 (1996): 6, https://arxiv.org/abs/quant-ph/9609002.
64. Here there is a clear isomorphism with second-order cybernetics. See Note 8 above and Collins's article on the Macy conferences.
65. For a clear explanation of this experiment, the reader unfamiliar with quantum physics is referred to the following resource by Jim Al-Khalili: https://youtu.be/A9tKncAdlHQ (accessed 11 November 2020). The best book-length exposition is currently Anil Ananthaswamy's *Through Two Doors at Once* (London: Dutton, 2018).
66. The most thorough book-length exposition of this is currently Philip Ball's *Beyond Weird: Why Everything You Thought You Knew about Quantum Physics Is Different* (London: Vintage, 2018), which has the advantage (for our purposes) of rapidly dismissing non-hyper-relational quantum mechanical accounts, such as the many-worlds theory.
67. On Fuchs, for instance, Christopher A. Fuchs, 'Quantum Mechanics as Quantum Information (and only a little more)', arXiv:quant-ph/0205039. On Zurek, see for instance, Wojciech Hubert Zurek, 'Environment-Induced Superselection Rules', *Physical Review D* 26, no. 8 (15 October 1982). On Mermin and the Ithaca Interpretation see, for instance, N. David Mermin, 'The Ithaca Interpretation of Quantum Mechanics', arXiv:quant-ph/9609013 and 'What Is Quantum Mechanics Trying to Tell Us?', *American Journal of Physics* 66 (1998): 753–67, where he states: 'Correlations have physical reality; that which they correlate does not.' This is as succinct a statement of hyper-relationality as we can hope to find. Other key references to hyper-relational quantum theory include: Mauro Dorato, 'Rovelli's Relational Quantum Mechanics, Monism and Quantum Becoming' (arXiv:1309.0132); Matthew Brown, 'Relational Quantum Mechanics and the Determinacy

Problem', *SSNR ((*27 March 2007), http://dx.doi.org/10.2139/ssrn.1006232 ; Bas C. van Fraassen, 'Rovelli'sWorld', *Foundations of Physics* 40 (2010): 390–417; Hans-Peter Duerr, 'Radically Quantum: Liberations and Purification from Classical Prejudice', in A. Elitzur et al. *Quo Vadis Quantum Mechanics* (Berlin: Springer, 2005), 7–46; Art Hobson, 'There Are No Particles, There Are Only Fields', *American Journal of Physics* 82 no. 3 (March 2013): 211–23, arXiv:1204.4616.

68. Not that the human observer is special in this regard; reality is created by interrelations even (and generally) without us around, which indeed is Rovelli's point – that quantum mechanics does not (pace some other theories) depend on a human observer or consciousness.
69. See, for example, Salvator Cannavo, *Quantum Theory - A Philosopher's Overview* (Albany: SUNY Press, 2009), which reads as such an extended complaint.
70. Rovelli, 'Relative Information'. In his latest book, published as this essay went to press, Rovelli clarifies the distinction between these two instances of information – the inanimate and animate – by combining information theory and Darwinian evolution, thereby physically grounding the notion of meaning for a living being as 'relevant relative information'. See Carlo Rovelli, *Helgoland*, trans. Erica Segre and Simon Carnell (London: Allen Lane, 2021), 145.
71. Ibid., emphasis added. In an article in *New Scientist* published as this essay went to press, Rovelli states similarly that 'the world is woven by relationships that go all the way down to the smallest physical entities'. But it is precisely the word 'entities' which fails here; relationships are not physical entities. Carlo Rovelli, 'Quantum weirdness isn't a weird – if we accept objects don't exist', *New Scientist*, 13 March 2021, 36.
72. Quoted in Rovelli, 'Relational Quantum Mechanics', 19. The quotation is from: W.H. Zurek, 'Environment-Induced Superselection Rules', *Physical Review D* 26, no. 8 (1982): 1878.
73. Zurek, 'Environment-Induced Superselection Rules', 1878. Ladyman's ontic structural realism makes precisely the same point.
74. For a recent discussion that ties the question of consciousness to entropy and information (although, I believe, not entirely succeeding) see Mark Solms, *The Hidden Spring: A Journey to the Source of Consciousness* (New York: W.W. Norton, 2021). The term 'hard problem of consciousness' comes from David J. Chalmers, 'Facing up to the problem of consciousness', *Journal of Consciousness Studies* 2, no. 3 (1995): 200–19.
75. Indeed it seems likely that quantum effects are relevant to this and other 'macro' biological questions. See, for instance, Jim Al-Khalili and Johnjoe McFadden, *Life On the Edge: The Coming of Age of Quantum Biology* (London: Bantam Press, 2014).
76. Baruch Spinoza, *Ethics, Treatise on the Emendation of the Intellect and Selected Letters*, trans. Samuel Shirley (Indianapolis: Hackett, 1992), 67 (Part 2, proposition 7, scholium). Deleuze, of course, regarded Spinoza as the prince of philosophers; see Deleuze and Guattari, *What is Philosophy?*, 48.
77. See Cedric Price, 'Anticipatory Architecture', in *Cedric Price Works 1952–2003: A Forward-Minded Retrospective* Vol 2, ed. Samantha Hardingham (London: AA Publications 2016), 460–467, 460, the transcript of a talk at Columbia University, New York in November 1995 where he asks 'remember the divorce?' A footnote explains that this relates to 'an anecdote told by Bernard Tschumi in his introduction to this talk in which Price was approached by a client who, wanting to do something to please his wife, asked Price to design a new house. Price reflected and responded that perhaps what the client really needed was a divorce.' Deleuze and Guattari speak of divorce in *A Thousand Plateaus* as the moment beyond the penultimate word in an argument, the moment when a couple enters another assemblage than that of marriage. Price is indeed pushing his potential clients into another assemblage. Deleuze and Guattari, *A Thousand Plateaus*, 438.

Biography

Tim Gough teaches design and lectures in the history and theory of architecture at Kingston University Department of Architecture and Landscape. He runs an architecture practice in London. His research interests include the work of Gilles Deleuze, Francesco di Giorgio, and phenomenology. He is currently completing a book on the ontology of architecture.