

Machines of Wonder and Elephants that Float through Air¹

A Valedictory Understanding of *Understanding Understanding*

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The paper stands both as a review of von Foerster's valedictory work "Understanding Understanding," and an analysis of what is argued to be the major theme in his work—wonder—examined through the material presented in "Understanding Understanding." The theme is developed with reference to three machines that recur in von Foerster's work (making several appearances in the papers collected in *Understanding Understanding*) namely, "Maxwell's Demon," "Eigen Forms" and the "Non-Trivial Machine," and is in turn related to the final paper in the collection. "Introduction to Natural Magic," which thus takes on the role of the key work of the collection.

Understanding Understanding

When Heinz von Foerster died on October 2nd last year (2002), he left a slightly incomplete collection of papers which, if anything is, is his valediction. *Understanding Understanding*,³ subtitled "Essays on Cybernetics and Cognition," is exactly that (Foerster, 2003). Here von Foerster has collected together many of the best known papers from the first part of his career in cybernetics, and supplemented them with a selection of later work, most of it also well known, but some of it nevertheless not easy to come by. He added an introduction (and there's an index). What is missing is the introduction he had intended to write for each paper he chose, and, of course, the title pages he himself designed for the versions he published through the Biological Computer Laboratory (BCL). It is a matter of considerable regret that he did not have the time and strength to write those introductions. I, for one, would have been fascinated to read his own evaluations and to hear something of the stories behind the papers that he would have liked to tell us.

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1. "Elephants that float through air" is a phrase plucked by one of my students, Nicholas Tidball, from von Foerster and Poerksen (2001). It was used to describe the sorts of wonderful things magicians convince us of.
 2. CyberEthics Research, Southsea, UK, email ranulph@glanville.co.uk
 3. Foerster, H. von (2003). *Understanding Understanding*. New York: Springer. All references to von Foerster's work cited in this paper are to be found in the papers collected in this volume. For that reason, publication details given are for the original publication. The details of this collection are omitted, save for page numbers which appear at the end of the reference in [] brackets, starting UU. For example, [UU 247-63].

The collection finishes with an oddball publication, “On Natural Magic.” Yet this paper now seems to me (for reasons I develop below) to be perhaps the key paper to his work. It sets the scene for the motivating idea behind this work: the passionate concern for what it is to be human (the theme of my paper), and it shows this idea forming and performing in von Foerster from a relatively early age.

In this paper I shall consider the material in *Understanding Understanding* both to explore it as the authoritative collection of von Foerster’s work, and in order to argue what I believe is the key theme to be discovered in his work through the examination of this collection.

The Papers

The papers in *Understanding Understanding* are organised more or less chronologically by date of their original publication, and fall broadly into two categories. Those papers, often with a fairly technical bent, in which the idea of second-order cybernetics can now (in hindsight, and in Heinzsight) be seen to be being developed; and those less formal and more philosophical and reflective papers which, assuming second-order cybernetics, talk about aspects of how we may understand ourselves and our places in the world, according to this new way of looking. I have appended a table (Table 1) in which I list the papers in *Understanding Understanding* in chronological (rather than book) order,⁴ comparing the contents of this book with the earlier *Observing Systems* which Francisco Varela composed and edited (von Foerster, 1981, see below), and differentiating the papers into these two categories (T for technical and P for philosophical), plus a third, transitional category (M).

The Technical Papers

Von Foerster’s reputation was built on what I call the technical papers. These papers start with his original (1948) venture along this path (“Das Gedächtnis: Eine Quantenmechanische Abhandlung” translated as “Memory: a Quantum Mechanical Treatise”⁵), which opened the door to the USA and to that extraordinary group of scientists that Heims refers to as “The Cybernetics Group” (Heims, 1991) who, recognising his worth, welcomed von Foerster to their number and set him the task of editing their proceedings so he would learn English (von Foerster, personal communication).

I call these papers technical papers because they are written (albeit in von Foerster’s wonderfully stylish English) in the mainstream of the tradition of the

4. Book order can be reconstructed from the page numbers.

5. This paper, a small book in the original German version, is not in this collection, but the problem it approaches is the key concept in von Foerster’s preface. The English version may be found in the first published proceedings of the Macy Conferences on Cybernetics which brought von Foerster into the cybernetic, and English language, community (von Foerster et al., 1950).

journal paper, and their arguments are often sustained by prolonged periods of complex mathematical formulation.

The technical papers in this volume may be directed towards cybernetics and cognition, as the book's subtitle tells us, but they could have been chosen for another audience. Of the half dozen technical papers presented in this book, most had already appeared in the earlier (and now impossible to obtain) aforementioned collection made by Francisco Varela—a biologist. The point I wish to make is that the papers in *Understanding Understanding* have a wider appeal than that suggested by the subtitle.

And they also move towards second-order cybernetics. Starting with the classic “On Self-Organising Systems and Their Environments” (von Foerster, 1960 [UU 1–20] concerning limits to self-organisation resulting from the Laws of Thermodynamics), these papers make a stately progress towards the equally classic “On Constructing a Reality”⁶ (von Foerster, 1973 [UU 211–228] which explores the presence of the observer in his/her way of understanding): perhaps the first paper actually to do—as opposed to derive—second-order cybernetics.

The progression makes the argument, albeit implicitly and (at least at first) unconsciously to the necessary inclusion of the observer which is von Foerster's requirement for a cybernetic system to transform itself to be second-order: as he wrote (in the “Cybernetics of Cybernetics” compendium, von Foerster, 1975):

First order cybernetics is the cybernetics of observed systems.

Second order cybernetics is the cybernetics of observing systems.

Being explicit, he describes the cybernetics of cybernetics in a paper of that name that appears later in *Understanding Understanding*, amongst those papers I have called the philosophical papers. However, looking back at the papers ranged under this technical heading, the development of the position von Foerster found himself moved to take, and the many contributions of his colleagues at the Biological Computer Laboratory, are plainly visible—given the distorting gift of hindsight! See also Scott (1979) and his extended paper in this Journal (Scott, 2003).

The Philosophical Papers

What I call the philosophical papers began to appear around the time of Varela's collection (1981), and so they are by-and-large missing from that collection. As an aficionado, I know many of them, but there are, nevertheless, a number I don't know, and some I was not even aware of. They are very different in style to the technical papers: far less formal and frequently using the device of a public lecture to give them

6. Apart from its own excellence, this paper is responsible for bringing George Spencer Brown's book *The Laws of Form* to wide public attention. Spencer Brown's dictum “draw a distinction” is von Foerster's abstract. The importance of the notion of distinction, and the debate surrounding both it and Spencer Brown's particular formulations, have been fertile.

a directness and inclusiveness that is new. Discussing this with others who care about von Foerster's work, the idea arose (from Dirk Baecker) that there were a number of events that coincided, leading von Foerster to take this new tack.

These papers start to appear at the time that von Foerster's legendary Biological Computer Laboratory at the University of Illinois was being closed. With von Foerster's retirement (in 1976), the university declined to continue supporting his Lab. Von Foerster therefore moved its materials and archives to his new Pacific home.⁷ This time also coincides with the period of transition in which the basic concepts of second-order cybernetics were developed and elaborated, which I have taken to be 1968 to 1975 (Glanville, 2002).

Thus, there is change in von Foerster's life, in how he thinks about the world, where he lives, his lifestyle and the sort of support he gets. Baecker suggested that, around this time von Foerster moved to communicate his ideas less through the somewhat private world of the learned journal, preferring public events and addresses where his presence as distinguished elder statesman (and his amazing ability to perform in public) gave him greater scope to develop and communicate his ideas. In fact, this became his preferred way of working. There were less and less occasions when he would write material that had not somehow been spoken: transcribing public lectures, or working in collaboration through interview (witness the three recently published books deriving from von Foerster interviews⁸).

From the above, it might be understood that I want to argue these papers are merely "chatty." This is not so. I call them the philosophical papers not because the technical papers were lacking in philosophical reference and content, any more than the philosophical papers are short on technical content (in particular, "Notes on an Epistemology for Living Things," (von Foerster, 1972a [UU 247–260]) "Objects: Tokens for (Eigen-) Behaviours" (von Foerster, 1977 [UU 261–272]) and "For Niklas Luhmann: 'How Recursive is Communication?'" (von Foerster, 1993b [UU 305–324]). I call them the philosophical papers because they approach wide-ranging questions that concern what second-order cybernetics is, and the way of thinking and understanding it brings, i.e., with what this understanding means to us as human beings. Thus, topics covered include responsibility; do we discover or invent; epistemology; and ethics.

A Key—or The Task

Everything I have written so far in this paper is scene setting, a placing of the offerings in *Understanding Understanding* in order and context. Yet my central task in this paper is not to review *Understanding Understanding*. It is to consider what might be called the "motivation" behind the content: to search for a common, deeply rooted

7. At least one advantage comes from this closure: when von Foerster realised it would happen, he used the elective he offered undergraduate students to provide the manpower to create the legendary "Cybernetics of Cybernetics" compendium which he edited (von Foerster, 1975).

8. See von Foerster and Poerksen (2001), Müller and Müller (2003), and von Foerster and Broeker (2002).

idea that may be seen to drive von Foerster's work—a key. This is not a typical review that summarises and places work in context. I would not want to do that as my part in commemorating von Foerster's work. Rather, I hope to show a special type of unity and of world view, a deep and unifying insight in von Foerster's work that will give us more than we have reason to hope for or expect! I undertake this by reference to an obviously cybernetic (in the original sense) aspect of von Foerster's work.

Let us remember that Cybernetics was, as Norbert Wiener described (1948), concerned with

“Communication and control in the animal and the machine.”

This cybernetics was specially interested in mechanism. What seems to me the greatest of the individual early texts, Ross Ashby's “An Introduction to Cybernetics” (1956) is almost exclusively focused on mechanism, and the where withal to enable mechanism to be developed. Early cybernetics was particularly concerned with the notion that the animal and the machine might be considered in the same breath: that, for the areas cybernetics was concerned with, there was no effective difference, and concepts associated with mechanism could be brought to bear equally on both.

So I shall start by examining machines von Foerster referred to with particular enjoyment.

Three Machines

Von Foerster liked too refer to three devices—the machines of my title. These three are:

- Maxwell's Demon,
- The Eigen Forms, and
- The Non-Trivial Machine.

The first and second of these are machines invented by others. Maxwell's Demon was invented by James Clerk Maxwell as a thought tool (in much the way that I claim we should understand the Black Box (Glanville, 1982)). Eigen Forms, a portmanteau term I use to indicate the whole gamut of “eigen” terms, such as eigen functions, operators, systems and values, have a long history going back at least to David Hilbert. Rather charmingly, a major current worker in the field of eigen forms has the surname, Eigen (German for “self”). The last of the three is, as far as I know, von Foerster's own invention, first appearing in von Foerster 1971 [UU 133–168].

I shall consider each of these machines in turn, although I shall not give (much) explanation of their mechanisms. I leave that to von Foerster himself, in the papers in *Understanding Understanding*. And perhaps I should also mention that I think I talk of these machines more metaphorically than von Foerster did. However, he was fond of quoting Gordon Pask (who he called “Mr. Cybernetics, the cybernetician's

cybernetician”) who defined cybernetics as “the science of the defensible metaphor.” (Foerster, 1991a [UU 288])

Maxwell’s Demon

Von Foerster introduces us to Maxwell’s delightful Demon⁹ in his paper “On Self-Organising Systems and their Environments,” (1960 [UU 1–20]): a paper of importance in a number of ways of which two matter here.¹⁰

The first is that it reminds us most clearly that von Foerster’s background is as a physicist. The theme of the paper, which surprised some, is that self-organising systems are subject to the Laws of Thermodynamics, and are therefore, in a profound sense, impossible. This was considered a strange conclusion for a man who had spent time and effort organising the conference on self-organisation at which the paper was delivered!

The second is in the introduction of Maxwell’s fabulous Demon, which makes further (and longer) appearances in “Responsibilities of Competence” (von Foerster 1972 [UU 191–9]), where he argued that Maxwell’s Demon is an isomorph of the Turing machine, an idea he repeated in “Disorder/Order: Discovery or Invention?” (von Foerster, 1984 [UU 273–282]).

Maxwell’s Demon is a device to counteract the operation of Newton’s Second Law of Thermodynamics. The idea is that this little Demon exists inside a box that has two halves, one hot, one cold, separated by a division with a small hole with a door. The Demon notes when low energy (speed) particles are trying to move from the lower energy half to the higher, and those of high energy (speed) trying to move from the higher to the half with lower energy, keeping the hot with the hot and the cold with the cold, by selectively opening the door. Energy is embodied, here, as temperature, and the (temperature) differential may actually increase. The point von Foerster develops is that it takes energy for the Demon to recognise the particles as hot or cold, and then to act to open or close the door, which dissipates the energy (temperature) differential regardless of the Demon’s conservatory efforts and antics. This means Newton’s Laws still hold, in spite of the Demon.

What, then, is interesting about Maxwell’s Demon? After all, it’s just a thought experiment and it’s neither real nor will it work. The answer is that it creates and maintains distinction (long before Spencer Brown’s imperious command! (Spencer Brown, 1968)). The mechanism of Maxwell’s Demon creates and maintains distinction, and without distinction it is not possible for us to develop understandings. Distinction makes possible our amazing ability to see and then to explain, and that is a sort of magic.

9. According to Dr. Albert Müller, keeper of the von Foerster archive at the University of Vienna, Maxwell introduced his Demon in his 1871 Theory of Heat. I am grateful to Dr. Müller for this (and much other) information.

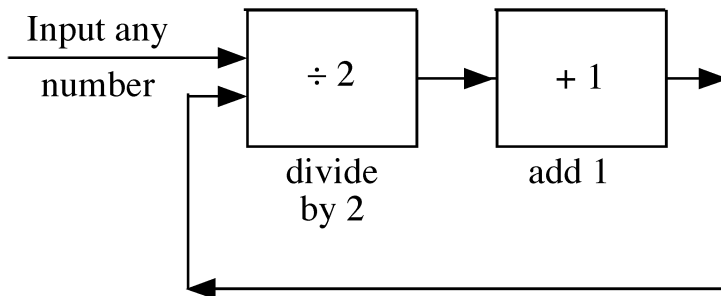
10. Bernhard Dotzler (1996) wrote about von Foerster’s interest in Magic and Demons in the Festschrift I edited for von Foerster (Glanville, 1996). However, his points (interesting as they are) are not quite those I make here.

Eigen Forms

Most who know of von Foerster's philosophical work will know of his fascination with Eigen Forms, introduced in his paper "Eigen Objects—Tokens for (Eigen) Behaviours" (von Foerster, 1977 [UU 261–272]) in which he explores the notion of recursive mathematical processes that yield a fixed, self-reproducing value regardless of the value of the input. Yet many people question the value of this fascination with Eigen Operations, Eigen Values, etc. They refer, in particular, to von Foerster's tendency to use the one example:

Take any number and apply the following action to it: divide it by 2 and add 1 to the result. Then repeat this process on this result, that is, use the output (result) of this operation as its next input.

This operation can be expressed in a diagram as shown below:



An Eigen Form that computes an output that recursively approaches the value 2.

The output of this iterative process always progresses towards 2. When it reaches 2 it retains that value. You can check how this can be by using 2 as the initial number you chose to input.

The general criticism seems to be that this is interesting, but only slightly so since it's not saying much. However, this is far too restricted a reading of what is a much more extensive paper, in which this is just one example; and too literal with this example which is, I contend, to be seen as a metaphor. As Kauffman (2003) shows elsewhere in this journal, Eigen Behaviours (and similar functions) are much more common than we might imagine.

Why was von Foerster fascinated with Eigen Forms? Again, Kauffman provides an extensive answer. But there is a simple root to von Foerster's fascination the key to which is, I believe, to be found in the connection he proposed when he first paraded his interest. The connection is with Piaget, and, in particular, with Piaget's concept of Object constancy—the mechanism by which we (starting as newborn children) learn to identify stable-under-change objects that we propose as the embodiment or

progenitor of a number of different percepts (Piaget, 1955). Thus, many different sensations that we eventually come to categorise as views, sounds, smells etc. which we encounter on many different occasions eventually come to form our notion of objects such as “Mum” (or whatever else). Piaget derived what he thought of as a necessary behaviour: von Foerster showed us a model of a mechanism that would generate this behaviour.

And this is, I believe, what he found magical about the operation of Eigen Forms: through them we generate, out of any random selection (out of nothing), a constant, recurring something. This operation shows us a way in which we can understand how (and that) we may develop constancy in our experience: how, from a world of no-form (no-world), we can generate a form or object—which we can attach to objects in the world (the world being such an object). (Of course, these objects are now the consequence of computations we carry out on our percepts, as von Foerster argues first in “On Constructing a Reality” (von Foerster, 1973 [UU 211–228].), a paper that became a clarion call to those concerned that the observer’s presence in his/her observations should be explicitly demonstrated and who wanted to understand what this might mean.

Von Foerster saw this as a way of bridging between experience and the world described in physics. As he often insisted (e.g., von Foerster & Poerksen, 2001), he was not a constructivist: but, then, he was not really any sort of -ist at all: he hated categorisation because it reduces our imagination and our freedom, makes it hard for us to see outside the bounds of the categories we saw—regardless of whether what we were seeing came from the (rest of the) world, or came from us.

The Non-Trivial Machine

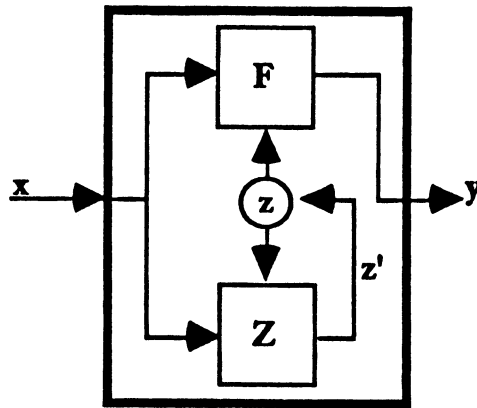
Von Foerster would often talk of the extraordinary processes of trivialisation that humans resort to. He regarded most education as a form of trivialisation, as he insists, for instance, in von Foerster and Poerksen (2001). By trivialisation, he meant that variety and difference were ironed out so that the outcome of any operation applied to the machine would be known (that is, perfectly predictable). This offended him greatly, for it offended against his dictate that “only we can decide the undecideable” by removing the undecideability through a conceit.

A conventional input/output machine converts an input signal or behaviour into a predictable output signal or behaviour. The machine is trivial because this behaviour is trivial: there is never anything to learn. Once you know one input/output relation you know that you know the resultant outputs deriving from all inputs.¹¹ Von Foerster held that if, in some system, you know the output that results from any input, that knowledge is trivial. As he wrote “A trivial machine is defined by the fact that it

11. Von Foerster discusses trivial and non-trivial machines in “Molecular Ecology” (1971 [UU 133–168]), “Perception of the Future and the Future of Perception (1972 [UU 199–210], and “How Recursive is Communication?” (1993b [UU 305–324]), although the language of his discussion develops in these papers.

always bravely does the very same thing that it originally did” (Von Foerster, 1993b [UU 305-324]).

In contrast, the Non-Trivial Machine, as von Foerster draws it, contains another input/output machine within it, which has a feedback loop generating internal states. As a result, the behaviour is simply not predictable: the possibilities are so vast that they cannot be examined.¹² And, while there may be times when the observer (that is, we) believe(s) (s)he has made a predictable model, there never is, and never can be, the certainty associated with the Trivial Machine. At some time the behaviour may change: we cannot know whether this will happen and, if so, what the result will be. In this respect, the Non-Trivial Machine is a variant on the Black Box (Glanville, 1982) and follows Wittgenstein’s (1961) insistence that because something has always happened does not mean it always will: historical constancy is not causal connection. See below:



A Non-Trivial Machine: note internal feedback loop.

It is the unpredictability of the Non-Trivial Machine that is significant to von Foerster, and that makes it non-trivial. What he values is precisely the unpredictability. Why?

Because the unpredictability means that we can anticipate surprise: all will not be as we had thought it would be. In other words, we have a model for a world we inhabit where what we observe may change in ways we cannot imagine. And that means we are never truly in control, that we can and must keep learning—maintaining our involvement. The world of the Non-Trivial Machine, as if by magic, creates surprises and cannot be tamed by us.

If the Eigen Form generates constancy (pattern) out of disorder and allows us to credit objects in our experience, the Non-Trivial Machine brakes these patterns, allowing us to discover the new, anew: it disorganises our ordering.

12. Von Foerster relates, here, to Bremmerman’s constant, a figure indicating what the earth might have computed in its life, had it been a computer. This constant, beyond which we move into areas of the transcomputable, is useful for giving a sense of scale and is not either absolute or correct. See Glanville (1998).

And Maxwell's Demon allows us to find and maintain boundaries in the continuum.

Wonder

Here, I want to substitute another word for the word "magic" I have purposely used, above.

What unites the three machines discussed above is that they all act to produce what causes us to marvel. We look at what they do—they are only machines, after all—and a sense of awe pervades us. They are amazing.

The word that pulls all this together is wonder. Not wonder in the sense of confusion, or wonder in the sense of dreamily being indecisive (I wonder about...); but wonder in the sense that we are left speechless—that transcendental sense that is more of the spiritual than the material world, which leaves us more aware of what it is to be human.

Here is what *Merriam Webster's Collegiate Dictionary* (as cited on the Encyclopaedia Britannica web site: www.eb.com) offers:

Main Entry:	1wɒnˌdər
Pronunciation:	'w&n-d&r
Function:	<i>noun</i>
Etymology:	Middle English, from Old English <i>wundor</i> ; akin to Old High German <i>wuntar</i> wonder
Date:	before 12th century
1 a:	a cause of astonishment or admiration: MARVEL <it's a <i>wonder</i> you weren't killed>
1b:	MIRACLE
2:	the quality of exciting amazed admiration
3 a:	rapt attention or astonishment at something awesomely mysterious or new to one's experience
3b:	a feeling of doubt or uncertainty

I refer, particularly, to the meanings listed under 2 and 3a.

Thus, I call the collective of these 3 machines the "Machines of Wonder," and title this paper accordingly.

Natural Magic

The last paper in *Understanding Understanding* is "Introduction to Natural Magic" (von Foerster, 1993a [UU 325–338]). This paper is a transcription by Paul Schroeder of a tape von Foerster sent him in response to a question Schroeder asked about his life as a magician.

This paper at first looks out of place in the collection. Yet it was a paper von Foerster was specially attached to, and he was most particular about its initial publication.¹³

All those who came across von Foerster learnt he was a magician, whether they came to know it in the liberal sense of the word, or the more technical. When he addressed an audience (numbering from 1 to 1000) he performed a certain kind of magic that brought you in to his world and his thinking: he was a performer.¹⁴

Fewer learnt that he was a fully qualified professional magician who, in his teens, had funded his interests in skiing and studying nature by performing magic in public with his cousin Martin Lang. He was a member of the (Vienna) Magic Circle!

I had always thought that what of this interest he carried into his work came through in the performance that he staged. But, over the last couple of years, I came to think this understanding was impoverished, too literal. As I came to understand the *Machines of Wonder*, so I came to understand that to be a magician is, as von Foerster insists, to have direct access to wonder, and to be able to bring it to others to create “Elephants that Float through Air.” This is what magicians do, and this is why “On Natural Magic” is both such an important paper, and so appropriately concludes *Understanding Understanding*.

Last Words

The special piece of magic that Heinz performed for me was to confirm this. He stayed alive long enough for me to visit him in late September 2002, and to ask him about wonder.¹⁵ He greeted me thus: “Ranulph, you are specialising in dying cyberneticians!” I took this as permission to ask those questions we don’t always feel we can ask the dying—although often enough, I have learnt, they wish we would.

I asked him many things. But in particular, I suggested that what he was really interested in, that what his whole life’s work had been about (and the key I have tried to argue for in this paper), was wonder, and the value of wonder. How he tried to bring that sense of wonder to the fore because it is through feeling that that we know we are human. And he replied, in that wonderful accent, that this was correct: in that diminuendo he used when he talked of the really important and the really personal, he agreed.

13. This paper, as with virtually all his papers, was published in a BCL version with a cover that von Foerster himself designed. I later tidied up the written transcription von Foerster gave me, and edited for consistency and publication, also attempting to convert very old, grey-on-grey photos to some form that might reproduce in the technology that journals use. Hence the acknowledgement to me in *Understanding Understanding*.

14. His son Thomas, who was responsible for the publication of *Understanding Understanding*, told me that von Foerster used to prepare at great length even to go out to dinner. I had seen him prepare speeches and was astonished at the efforts he took to present thoughts and work he was already a master of, although I have since found the value in this approach, which I find echoed in the Scottish comedian, Billy Connolly

15. He passed into a semi coma the day after I left and died a few days later. I was, as far as I can tell, his last visitor, apart from family and other intimate carers

Coda

There is another device that von Foerster used, another pithy aphorism I mentioned earlier, that perhaps lies behind all of this. He was fond of saying:

*Only we can decide the undecideable.*¹⁶

By this I believe he meant the following:

When some question is in principle undecideable, when there can be no mechanism for making a decision, then the decision is up to us, and only we can make it. The choice is ours. One such is the question of whether there is a reality we can know that is independent of our knowing it (a mind-independent reality): clearly we cannot know if there is a reality we can know without knowing it. We cannot decide this question, so we are free to make our choice according to our personal taste: the decision depends on who we are and our belief systems more than, perhaps, any other decisions. The decision we make tells us who we are.

The decision of whether anything exists when the observer is removed is the question that fires constructivism. There appear to be two answers: either that there is a mind independent reality, or that there is nothing. For a constructivist, I think that this question should remain undecided. But von Foerster was prepared to live at least as if there was a mind independent reality (the sort of reality science looks for). He looked on this the way he looked on mathematics: as an elegant, delightful and convenient device that allowed him to get the results he wanted more efficiently and effectively (he likened the use of mathematics to riding a subway train to traverse a city). What is important, however, is not so much the choice he made, but that there was a choice for him to make.

And that, we agreed, was the greatest wonder of them all.

Acknowledgements

Drs. Bernard Scott, Albert Müller, Karl Mueller and Dirk Baecker have helped me with sources and comments. Aartje Hulstein, Søren Brier, Paul Pangaro and Thomas von Foerster all read manuscript drafts and made many helpful suggestions.

Madeleine AkTyPi, in a long interview conducted through email (Glanville & AkTyPi, 2003), reminded me of the importance of the quote “Only we can decide the undecideable.” Thank you Madeleine.

16. Concerning the source of this quote, Albert Mueller notes: This theorem was created within the context of a lecture Heinz gave for the ars electronica festival on Sept. 14th, 1988. The paper is published as von Foerster 1989. This publication had—as far as I can see—two German reprints but no translation into another language. Heinz took up this sentence (theorem) in an article for a volume on research on reflexivity, published as 1991b. Heinz came back to this sentence on the occasion of his “Paris Paper” which he gave to the conference “Systèmes et thérapie familiale” in October 1990. There, he no longer speaks of a “theorem” but of a “metaphysical postulate” This paper is published as Heinz von Foerster (1991a). The next year an English version appeared in *Cybernetics and Human Knowing* 1(1).

The opinions and arguments remain mine, and I own all the mistakes. They're mine, too—mine, all mine!

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Note: von Foerster's papers not originally presented in English appeared in private BCL publications. Where a non-English language paper has been cited, the English version read by the author is always the BCL version.

Appendix: Table 1:

A comparison of two books comprised of selections from von Foerster's papers

DATE	<i>OBSERVING SYSTEMS</i> (1981)		<i>UNDERSTANDING UNDERSTANDING</i> (2003)
1960	On Self-Organizing Systems and their Environments, 1-23	T	On Self-Organizing Systems and their Environments, 1-20
1964	Molecular Bionics, 71-90	T	
1965	Memory Without Record, 91-137	T	
1967	Computation in Neural Nets, 24-70	T	Computation in Neural Nets, 21-100
1969		T	What Is Memory that It May Have Hindsight and Foresight as well? 101-132
1970	Molecular Ethology, An Immodest Proposal for Semantic Clarification, 149-188	T	Molecular Ethology, An Immodest Proposal for Semantic Clarification, 133-168
1970	Thoughts and Notes on Cognition, 231-256	T	Thoughts and Notes on Cognition, 169-190
1971	Technology: What Will It Mean to Librarians, 211-230	T	
1972	Perception of the Future and the Future of Perception, 189-204	M	Perception of the Future and the Future of Perception, 199-210
1972	The Responsibilities of Competence, 205-210	P	The Responsibilities of Competence, 191-198
1973	On Constructing a Reality, 287-309	P	On Constructing a Reality, 211-228
1974		P	Cybernetics of Epistemology, 229-246
1974	Notes on an Epistemology for Living Things, 257-272	M	Notes on an Epistemology for Living Things, 247-260
1977	Objects: Tokens for (Eigen-) Behaviors, 273-286	M	Objects: Tokens for (Eigen-) Behaviors, 261-272

DATE	<i>OBSERVING SYSTEMS</i> (1981)		<i>UNDERSTANDING UNDERSTANDING</i> (2003)
1979		P	Cybernetics of Cybernetics, 283-286
1984		P	Disorder/Order: Discovery or Invention? 273-282
1991a		P	Ethics and Second-Order Cybernetics, 287-304
1993		P	For Niklas Luhmann: "How Recursive is Communication?" 305-324
1993		P	Introduction to Natural Magic, 325-338

Transfinity

666 said the moon child.

Ride with me and your hidden devils can get wild

To get back on the home path, you might need reason, or a little math.

If you want to be a mathematical hero, begin with a point, and a zero.

With one you get some, and the possibility of unity.

Two leads to the pair and square,

Angles that are right create height.

Three makes perspective, and the cube,

Now look at the next higher dimension in a telescopic tube.

With four you can enter the time door.

Entropy won't let you go from now to before.

Lines of time end in death,

But this is a shadow of the next dimensions - light and breath.

Time is also rotation, circulation and duration measured by infinity to the infinite power,

And now we stand on a transfinite tower!

Has logic become phantasy?

You might need intuition to return to reality!

Bill Schiffer

The Cosmic Flower

Christiania

Copenhagen, Denmark

