Tools for managing the interconnections between Nature and human society within an information processing architecture

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1 Introduction

If information were considered a nutrient in the development of a complex society then important considerations become: what information, in what form and where is it needed?

For a technology that utilises the biosphere then the complexity of Nature will always be present. The question is, how we access this information and use it to shape our technologies and how these technologies are used to maximise their usefulness to society, which includes its long term survival.

There are a range of tools for this task that attach to the continuum between Nature and human use of Nature. The potential creativity of the boundary between Nature and human use of Nature is explored by considering the differing tools and uses of these tools from the whole continuum:

- At the Nature end of this continuum are precise tools that utilise the mathematical formulations of Nature's processes.
- In contrast, the human side of the *human use of Nature* boundary contains all possible technologies for which the detail of Nature is present but impossibly complex. At the human side of the boundary pragmatic tools are needed to ensure that the most relevant parts of Nature are heard through the cacophony of social processes.
    - These pragmatic tools range from those with strong linkages to Nature, such as: simplified approaches (e.g. using a single rate constant in a cubical container), information conduits, sustainability as a purpose and the Beacon; to
    - Pragmatic tools with strong linkages to the social domain. These include: prioritising the sustainability zeros for the local environment, information packaging for each technology (enabling sorting of available technologies), and quantification of a technology's location on the perfect/useless continuum which can be linked to the economic system.
    - It is also possible to consider tools that have strong linkages to both Nature and social functioning. For example, linking the effect of individual variability to the cost of a sewerage treatment station forms an information conduit between Nature and the economic system (Chapman, 2015c).

This paper summarises the range of tools that can be used by considering the role of information in a complex society.

Creative solutions can arise from use of these tools and some of these possibilities are explored. The paper ends with a discussion about possible common behaviour patterns of complex systems, particularly the notion of an interaction in a context with the contexts being held in hierarchies.

We can give Nature a voice in the boardroom (and communities) that has a different mechanism to the exercise of law. Human society would be better off if it were used.

2 Summary of related work

In Part I of this series of papers I argued for the development of an *information processing architecture* composed of information processing structures (Structures), consideration of the boundaries and the interconnections between Nature and human (Chapman, 2013). Part I built a part of this Architecture around Nature's Structure with the upper mathematical boundary coinciding with the physical boundaries of a technology. In addition, a *system* physical boundary was argued to be possible around an assemblage of technologies that enabled environmental effects to be included within Nature's Structure (such as sludge disposal and adverse environmental effects on lakes and rivers). This *system* boundary meant it was possible to consider the role of our technologies in influencing the path of the components of sewage (water, nutrients, pathogens etc) through the great planetary cycles. Our deleterious environmental consequences arise from these planetary paths and hence are included within the analytical framework of such an Architecture.

Part II considered the possibility that the Architecture could include human complexity by considering each of our organisational forms (commerce, institutions and our communities) as separate Structures (Chapman, 2014c). In the information realm, this could be answered in the affirmative if each organisational form could be viewed as a semi-autonomous Structure with interconnections carrying information between them.

These human organisational forms retain their information linkages to Nature if Nature's Structure is included. Thus, for using technologies to minimise human environmental effects then Nature's Structure is interpreted using sustainability criteria (such as zero water, zero energy and nutrient recycling) and this interpretation used to design a technology that is manufactured within the commerce Structure which in due course is purchased by a member of a community Structure; resulting in a decrease in environmental discharges. Mechanisms to influence human environmental consequences therefore can include encouraging commerce to generate the best technology (which is informed by the science underlying Nature's Structure) that can be applied to waste streams at their source in the community. This is a different mechanism to regulation of discharge minimums for reducing our environmental impacts.

But equally we can **exclude** from the question elements that are problematic, and this can be a serious issue for human habitation on this planet. The complexity is daunting necessitating an initial decision about how to approach Nature's Structure but this means it is easy for us to be selective about which parts to consider. Discharge of raw sewage to rivers occurred because it was (and remains) the cheapest method. The history of sewerage contains several examples of these 'externalities' being legalised (Benidickson, 2007).

With our values being able to influence any approach to a Structure then the task for this paper is akin to an archaeological excavation where the precious bits need to be carefully separated from the unnecessary bits, with minimal influence from human foibles. The boundary between Nature and Human use of Nature is potentially very creative and the manner of human interaction with Nature's Structure (within the *architecture)* can help or hinder release of this creativity. It is therefore very important if the best decision is to be made to release this creativity.

This paper overviews this boundary and the tools that can be used to extract the creative potential that is inherent in it.

3 Information as a nutrient

Information in a complex society plays a similar role to nutrients in the plant world, get the mix right and healthy forms grow. In a study of phosphate flows around the world, Cordell et al. (2009) separated the anthroposphere (food-related human activity using phosphorus) from the natural environment (phosphorus flows in biomass, land and water). Such a division between human and non-human is particularly useful for understanding the information flows being discussed here.

With the complexity separated into Nature and human with interconnections between them, the focus can move to the interconnections and the information that they carry as a form of nourishment to build a healthy society. Indeed, systems thinking argues that information feedback loops are an important component of the behaviour of the 'system' (Meadows & Wright, 2008); separating out these interconnections gives an attachment point for these system feedback loops. There are a number of tools that humans can use to access Nature's Structures that in effect enable optimisation of the information flow.

Precise tools directly access Nature's Structure and give an answer that is a value in a mathematical parameter. The optimising parameter for composting (Chapman, 2011a) for example will give a different value even if you only change your diet – as the proportion of fast fraction to humification fraction is influenced by the food that you eat (more particularly the ease of digestion of the food, as faeces are the indigestible portion of this food). This small change will result in a different distribution of oxygen in the pile and consequently a different value of Φ. Precise tools will be mostly used by commerce and engineering. There are three ways that the precise tools can utilise Nature's Structure:

- The questions **directly** influence the output of Nature's Structure and this output is used to guide decisions, such as:
    - "What would be the effect of changing X?" type of questions; where X can be any element of design, operation, climate, or level of use.
    - The value of an optimising parameter arises from the direct connections. By choosing the parameter based on its high correlation to an important performance parameter this correlation 'shapes' the information for human use (Chapman, 2011a). Optimising parameters cut a surface through the complexity that can be viewed graphically if desired.
    - Sustainability questions are also a form of direct influence that enter via the mathematics of minimisation.
- **Move the boundary** around Nature's structure. Using the pre-technology boundary focused the analysis on the volume and chemistry of each of the 3 waste streams in Chapman (2014a), a useful starting point for critiquing the incumbent sewerage system.
- Utilise an **interface** between the Structure and human use and make this boundary creative. For example, the optimising parameter can interface with a 'commercial' curve (which contains information on the performance/cost characteristics of a technology). This interaction is argued to identify the existence of commercial niches in composting (Chapman, 2011a). The emergent property of commercial niches arises from the *interaction* of the optimising parameter with social/commercial data (see Figure 2 below). The profit motive

thrives on commercial niches and contains powerful forces that can drive a technology's development.

Pragmatic tools in contrast knowingly compromise precision in order to identify the 'patterns' of behaviour that are useful for social interaction. The social interface needs to facilitate choice between competing technologies; or generate information signals for commerce if these technologies are found wanting. Tools such as:

- Form an information package (such as measured performance, energy consumption, cost etc) around each technology.
- Sorting these information packages according to the most important local priorities.

In addition, pragmatic tools can:

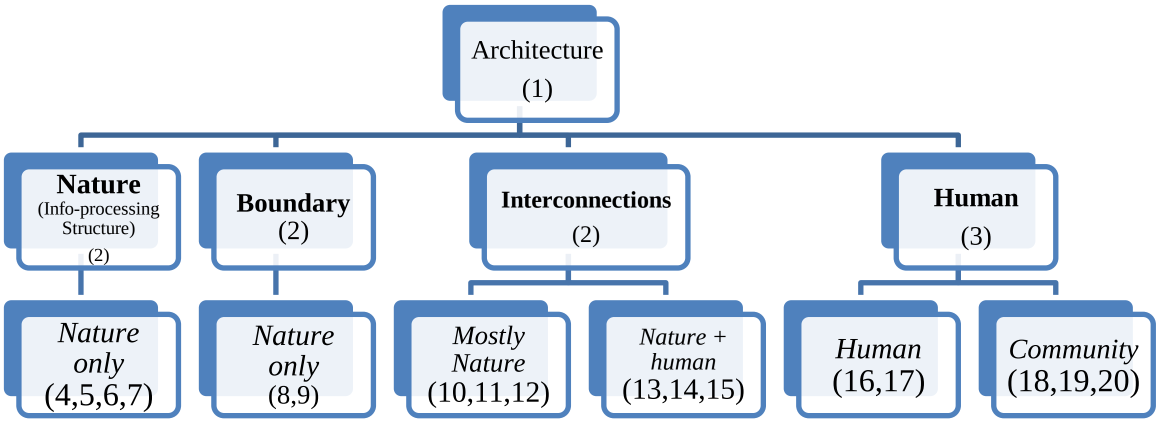
- Utilise the commercial forces noted above by articulating the **desirability** of having a technology that fills a particular niche – a community which is looking for a technology that uses no water, enables recycling of nutrients, and is resilient to natural disasters identifies a commercial niche for which an astute business would realise could put them 'ahead of the pack' – as many more communities will realise the advantages of such a technology. This is in effect passing information to the commerce sector that encourages development of more appropriate technologies.
- Human activities can be influenced by the **existence** of the information, for which there are many forms that the information can take, and many mechanisms by which the influence occurs. For example, the 'Beacon', discussed in Chapman (2013), is *sustainability perfection* so it not only satisfies all of the purposes of the council's governing Act, but can also fill an inspirational role for commerce. It can also be used in the public debate as the Beacon generates a useful **tension** between *where we are* and *where we could be*. Over time this can move society towards sustainability. A different application, useful for communities, involves conveying the environmental consequences of technology choice to the decision maker encouraging them to choose the better performing technologies; discussed in Chapman (2017d).

Due to the amount of information inherent in Nature's Structure, each tool can only capture a part of the complexity. The captured information therefore needs to be most relevant for the tasks required of the technology, for which several tools can be used in series and/or parallel to extract more wisdom from the complexity. While each tool may be used in isolation, no single tool could be considered to be perfect. Some will be better suited to a particular task than others and these would be the preferred ones to use; but the best tool will always remain task specific.

Optimisation of these information flows involves consideration of choice of tools, which information they capture and how this information is used. In the information realm internalisation of environmental effects can be formulated as a tension between where we are and where we could be. This tension then only needs a mechanism by which it can access the mind of the decision maker to effect a change in the decisions we make.

The optimisation question in the information realm can be viewed as a journey through the boundary that is facilitated by the full range of tools that are available.

4 Summary of the tools and their associated papers



Ref #	Title
1	(Using an information processing architecture as an aid to optimising technology choice for faecal wastes and domestic waste water: Part I - Encapsulating Nature.)
2	(Tools for managing the interconnections between Nature and human society within an information processing architecture)
3	(Using an information processing architecture as an aid to optimising technology choice for faeceal wastes and domestic waste water: Part II - Human complexity)
4	(Parameter determination in composting - Part I: The use of overlaying, interdependent sets of equations as a solution to the over parameterization problem)
5	(Parameter determination in composting - Part II: Incorporating substrate diffusion and substrate solubilisation)
6	(Parameter determination in composting - Part III: Analytical boundary)
7	(Modelling composting complexity: the use of emergent, information rich, computational units as a solution to the over parameterization problem)
8	(Bottom-up modelling from the chemistry conjunction: building information processing structures that encapsulate the essence of the complexity of any system.)
9	(Navigation tools for complex systems: Seamlessness, rootedness and constraint resolution as aids to pattern-oriented modelling - Insights from ecology.)
10	(The use of context and hierarchies to extend seamlessness into technology choice)
11	(The Beacon)
12	(The derivation and use of an optimising parameter for incorporating information into the decision making process)
13	(Applying sustainability criteria to the separate treatment question: Insights from the application of an information processing architecture)
14	(Enabling sustainability in the wastewater industry by finding space for primary adopters: Part I - Mass balance and microbial kinetic linkages to individual variability)
15	(Enabling sustainability in the wastewater industry by finding space for primary adopters: Part II - Economic linkages.)
16	(Opening information feedback loops as an aid to good decision making in a complex world: a sewerage case study.)
17	(Embedding fairness and equity values into a community sewerage system -

	mathematical version)
18	(A sustainable sewerage system for Glenorchy)
19	(Using scale and conveyance of the environmental consequences of technology choice to the decision maker to build sustainability criteria into Glenorchy's sewerage decision)
20	(Dealing with Glenorchy's faeces urine and greywater - grasping the potential by thinking differently)

5 Adding creativity to the mix

Optimisation is more than just engineering. In a short review of the history of sewerage systems the authors concluded that sewerage systems are "*not especially clever, nor logical, nor completely effective – and it is not necessarily what would be done today if these same countries had the chance to start again*" (Feachem, Bradley, Garelick, & Mara, 1983, p. 64). Engineering can take care of the logic component of Feachem et al's description, but there is a need to incorporate *effective* and *clever* into our technologies. These aspects involve people, their sense of place, passions, and economic well being.

Creativity is a boundary effect, the contrast between colours in art or the punch line that differs from expectation in the stand-up comedian's act. The inventor who says "no one told me it was supposed to be impossible". Life itself is a boundary phenomenon as it occurs at the boundary between the lithosphere and the atmosphere when an energy source is available. But within the biosphere there are ecological niches – boundaries within boundaries. At the boundary, Nature becomes impossibly complex (Figure 1).

However, not only is this part of the essence of life but this is also where we create our technologies. Consider a community's optimum technology (point X in Figure 1) as an interaction between Nature and human, each with their attendant complexity. The solution involves moving both the Nature and human curves in a manner that they intersect at the optimum technology. In this case the sustainability zeros put a constraint on the range of possible technologies while on the human side is the need to facilitate the role of early adopters particularly if the cultural mores discourage the more sustainable technologies:

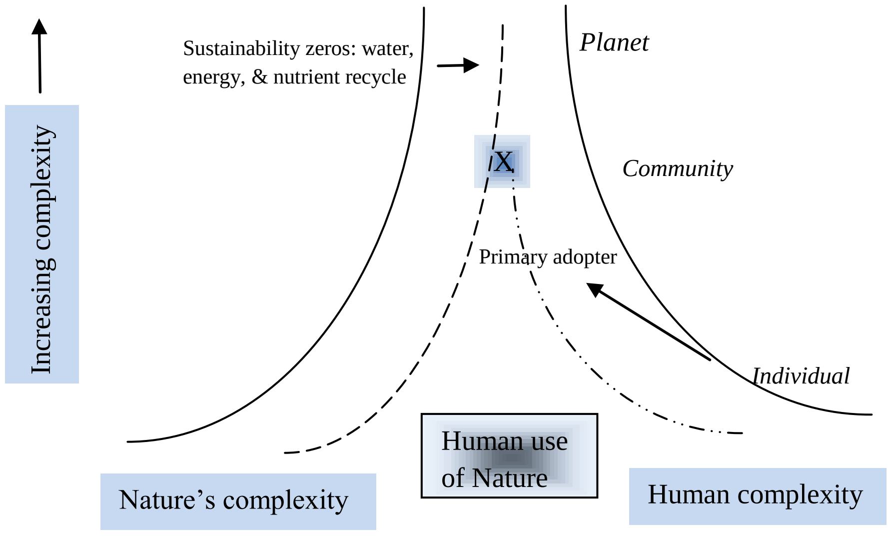


Figure 1 – Diagrammatic representation of the location of a community's optimum technology (X) in the complexity continuum. The task reduces to mechanisms to find X in the 'fog' of complexity that includes all possible technologies. Sustainability as a design requirement can be embedded within the Beacon and consequently pass through X. While on the human side the failure of the industry to move towards more sustainable technologies can be bypassed by acknowledging the spatial and temporal variability within a community and favouring those individuals who are likely to choose these more sustainable technologies. This will allow the community to move towards more sustainable technologies over time.

These elements form the basis of the Glenorchy sewerage study in Chapman (2015a).

However, utilising these boundaries can have many forms. Consider a technology-specific example that uses a technology's optimising parameter. In Figure 2 the optimising parameter (aerobic proportion in compost toilet technologies (Chapman, 2011a)) has a minimum lower value at which odour production renders a design unsuitable. Above this minimum value a range of 'acceptable values' mean the design performs satisfactorily. However, designs that have a high aerobic proportion are likely to be more expensive to manufacture, hence commerce can produce a range of designs for which the correlation between cost and performance means that a range of commercial niches become available to these commercial actors. In Figure 2 the technology specificity arises from needing to meet the constraint imposed by the sustainability zeros (A), so human survival on the planet and the full range of possible technologies are included.

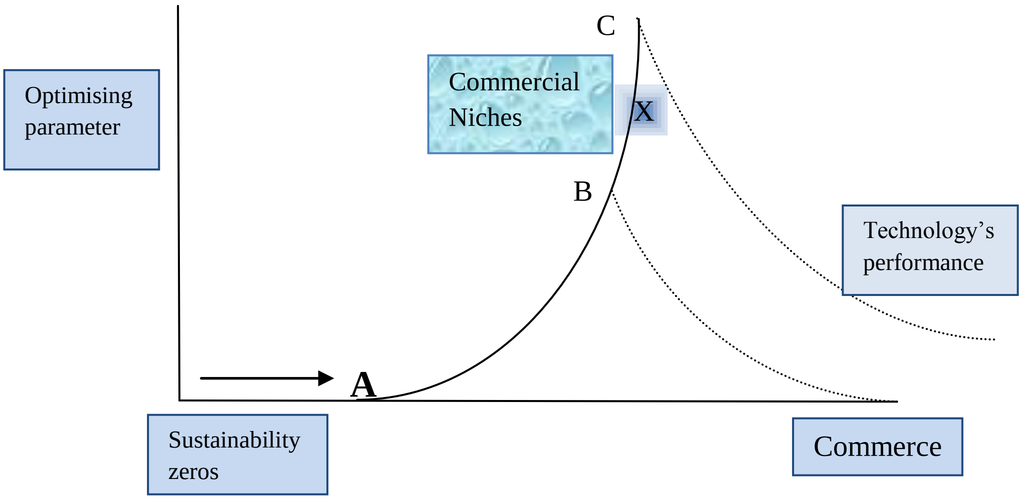


Figure 2 – Diagrammatic representation of the interaction between the optimising parameter (with information linkages to the underlying science) and performance of a range of manufactured technologies. Notes: 1/ that use of the optimising parameter means that X is optimised for the microbial performance while using the sustainability zeros will mean that point A includes the most sustainable technologies.

However, creative boundaries also exist in science. The Medawar zone of Grimm, et al. (2005) is that point of model complexity at which maximum *understanding* occurs. Maximum understanding is not necessarily the same as maximum knowledge; particularly if the 'patterns of behaviour' are swamped by too much detail – hence the saying *you can't see the forest for the trees*. The Medawar zone is an ecological adaptation of a concept first proposed in the philosophy of science by Loehle in 1990. By analogy, meshing technology development with human functioning would be impossibly complex if you included the micro-environment of every bacterium in your treatment station, yet these bacteria are present in the system and necessary for its functioning. There is a need to simplify to make sense of the system. Indeed the semi-autonomous organisational forms discussed in Chapman (2014c) are a form of simplification. Simplifying using these organisational forms serves a different role to the *navigating* tool using bottom-up modelling (Chapman, 2010a); which is diagrammatically represented in Figure 2 by the movement of the left hand curve to pass through the optimum.

Creativity also resides in the efficacy of the tools that we choose to use.

However, the observations of sub-optimality within the industry discussed in Chapman (2013), points to the need for mechanisms that help the industry develop more sustainable technologies – the right hand side of Figure 1. For which an alternative to *forcing* the industry to improve is to consider the creative potential that lies at the boundary between the three systems (community, commerce and our institutions). The use of information feedback loops for this task is explored for application to Glenorchy in Chapman (2017d).

Nature can have a voice, as her information can be put in a form that begs consideration.

Nature's voice can take many forms, the effect of using less water and fitting nutrient capturing technologies on the capital (and operating) cost of a sewerage treatment station can be quantified and formulated into an economic signal (Chapman, 2015c). This economic signal creates an incentive for a household to use less water and invest in nutrient capturing technologies and consequently puts sustainability issues (water, nutrients and energy in the case of sewerage) into the decision framework at the individual/household level. An *information conduit* is formed between Nature and an individual (or dwelling). This enables the spatial variability within a community to express – thereby avoiding the "tragedy of the commons" that is implicit in council taking full responsibility for our three waste streams.

If our social structures (and behaviours) reflect the underlying 'ecology' of the planet then the possibility of empathic behaviour within individuals becomes an alternative to the coercive manner implicit in the exercise of power. This alternative is not in the manner of supplanting the exercise of power but enhancing it, as any changes then become embedded in the community's culture. Our brains have used culture as an organisational form for millennia, far longer than the Resource Management Act has been in existence and culture is far more accessible to the individual than the law. The role of the primary adopter in Figure 1 is in effect 'information' about *what is possible* in a culturally acceptable form.

This is a different mechanism to the coercive manner of the law and can sit alongside our legal framework. We can not only link our environmental footprint with commerce, institutions, and communities but also to the very purpose of our governing act by linking personal choice to our *economic* and *cultural* well being.

Not only are the instruments in the orchestra in tune, but when playing a fine piece of music, raises the net result to something of beauty.

6 Discussion

There are a number of levels within the interface between Nature and human use of Nature by which humans can extract useful information – each level needing the information to be formulated for the particular use.

The human domain tends to be organised into sectors, and hence the term levels may not apply literally, however it is suggested that this use of information in the social domain can be viewed as analogous with the use of hierarchies and context that was found to be useful for organising information in building bottom-up models from the chemistry conjunction (Chapman, 2011b). For bottom-up modelling the use of an *interaction in a context* was argued to be common across a range of different scales, while the use of *hierarchies* was argued to be a useful holder of all the contexts.

When applied to the social domain an example would be the technology hierarchical level, where the commercial niches that arise from the interaction between an optimising parameter and a commercial curve, occurs within the context of nurturing the best possible compost toilet technology for the use characteristics at the particular site. Similar hierarchical levels are possible when formulated for institutional use – sustainability as a purpose for example is between all technologies and the use of Nature in these technologies (more particularly the consumption of *natural and physical resources*).

At a different hierarchical level are the community processes around deciding the best combination of technologies for dealing with 'wastes'. The interaction is between the competing technologies (which are a product of the technological hierarchical level); while the context in this case is the socio-economic conditions of the community and its local environment. The requirements for human sustainability therefore can be arranged in a hierarchical form with each hierarchical level formulated to best serve the needs of its particular context. There being interactions *between* the contexts, in addition to interactions *within* the contexts.

While using hierarchies and interactions in contexts is one way of organising the information inherent in the full complexity, let us not assume it is the only way. Consider the following arrangement based on the intended use of the formulation:

- Computation suitable – In addition to the derivation of information-rich parameters that can participate in building more complex Structures, are the mathematical procedures of minimisation used to include the sustainability purpose. Also the physical forms (such as a technology) which can be used by community members for the iterative procedures mentioned above. For community tasks the information needs to be:
- Brain suitable – in particular the human brain has trouble with mathematics but is very good at processing 'chunks' of information. There is no theoretical reason why considerable useful information cannot be incorporated into each chunk and in this manner be incorporated into the subsequent decision. The performance of an existing technology is in effect a 'chunk' of information.
- Sector suitable – identification of commercial niches for the commerce sector is discussed above but there is no reason why other formulations can't be derived for particular institutional use. For example, incorporating environmental data into information feedback loops provides an alternative mechanism for councils to manage environmental impacts.

Consider a further subset of the information based on the **tensions** that arise between components of the complexity:

- The Beacon which can:
    - Serve to inspire an inventive person/company to develop new and better technologies.
    - Draw a community decision to the most sustainable option within their economic limits.
    - Enable fiscal measures to be based on a quantified assessment of where on the perfect/useless continuum each technology occurs.
    - Used to give a marketing advantage to the most sustainable technologies.

    - Disadvantage an underperforming technology that may attempt to use marketing strategies to rise above its competitors.
- Perpetually scrutinise an institutional stance which may be sub-optimum, leading to gradual change in the stance that does not involve political or legal action.
- Allow councils to adopt a different role to the current coercive one by enabling: a range of fiscal measures which can be based on a measure of perfection relative to the Beacon and/or, develop methods for helping the community sort the performance data that is necessary for them to choose the best option.
- Boundary locations: where setting the Nature: human use of Nature boundary pre-technology results in a Structure that applies in many different technologies, enabling an external critique of incumbent technologies.

These tensions have their own usefulness for the long-term direction of a developing complex society.

Finally, the computational power of structure was argued as the reason why onion ring type volumes of compost (micro-environments) could reduce the composting complexity to a simple mathematical sum. There are similarities between the compost experience and the arguments above with respect to chunks of information participating in the public debate. Mathematics works by building information into symbols that can be manipulated according to the rules, and chunking of information for use by the brain is not inconsistent with this aspect of mathematics. Indeed an abacus could be argued to be based entirely on the computational power of structure (the complexity of computation is embedded in the position and rules for movement, of the beads).

There is a need for some sort of information organising system as optimisation of a technology is only one part of a far larger potential. Social processes can more effectively process information if the characteristics of each component of this complexity are considered in the formulation of an Information Processing Structure. In effect, the architecture includes this subtlety of the social interaction. In this respect, an information conduit's role in information use by a complex society is not necessarily that much different from the role that surface proteins play in the life of the cell. Information conduits can be 'shaped' for the particular information transfer, just as the surface proteins can be 'shaped' to take on a particular type of messenger molecule. The richness of the interaction between humans and human use of Nature is likely to be maximised if the best organisational system for the specific task is chosen. Indeed all of the information organising systems mentioned in this discussion have been used at various points in this analysis (interested readers may like to locate these through the bibliography below or the summary in Section 4).

7 Conclusion

Nature's limit as captured in a Structure is only one of the constraints within which a technology operates. A technology exists between Nature and the social context. Consequently, a technology has roles as both a container for Nature's processes and meeting human goals, such as preventing the insect vector for pathogens. There is therefore a limit to any Structure's role in the design of a technology; the technology utilises Nature, but must also answer to society. However, the creativity inherent in the complexity of a boundary means that we can locate the boundary at the point where we want the creative solutions to manifest – that is:

- At the commerce/engineering/science junction when we want the best possible technology for any particular application. Arranging the information flows to meet at the point where technologies are formed enables some notion of optimisation to be applied to the information

before it is used to derive a particular technology, such as the desirability of mixing the 3 waste streams versus separate treatment of each.
- At the technology/social use of this technology junction when a community is making decisions around the suite of available technologies for dealing with its three waste streams.

A range of different interactions with a Structure have been argued to be possible to assist in the passage of information into human decisions. In effect, including the full complexity in the starting assumptions means that tools are needed to navigate through the complexity to the best location. Each tool will have a set of characteristics that arises from the part of the complexity that it accesses and how it responds to questions, so tools can be formulated for specific tasks. However, all tools should reside in the 'toolbox' until it is apparent which tool is best for the particular task. The first task therefore is to consider the purpose for which the information is required, if only to avoid wasted effort designing a sub-optimum technology.

There being a range of possible tools that can be used, and no reason why several tools cannot be used concurrently, means that there are a number of possible ways of interacting with the complexity. This raises questions of optimality as to the best way of interacting – which includes the combination of tools. Indeed, it is argued that this 'space' can be made creative by allowing Nature (via its associated Information Processing Structure) to identify what may be an unattainable technology, but which never the less can shine through the complexity in the manner of a beacon guiding a ship. This is a very useful concept as it enables a weighting exercise to occur when the inevitable compromises arrive. These compromises arise from the messiness of social processes, for which a variety of tools can retain all the complexity in the process, yet enable a technology to manifest.

This provides an incentive for development of improved technologies for the future and can act through commercial processes.

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