THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Innovation in Complex Adaptive Systems

PETTER TÖRNBERG

Department of Energy and Environment
Division of Physical Resource Theory, Complex Systems Group
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2014

Innovation in Complex Adaptive Systems
PETTER TÖRNBERG

Thesis for the degree of Licentiate of Engineering

Department of Energy and Environment
Division of Physical Resource Theory
Complex Systems Group
CHALMERS UNIVERSITY OF TECHNOLOGY
SE-412 96 Göteborg
Sweden
www.chalmers.se
Tel. +46-(0)31 772 1000

Author email: pettert@chalmers.se

Printed by Reproservice
Göteborg, Sweden 2014

Innovation in Complex Adaptive Systems

PETTER TÖRNBERG
Department of Energy and Environment, Chalmers University of Technology

Abstract

Our society is increasingly beset by a range of interrelated crises - with the financial crisis, the energy crisis, and the global warming crisis as leading examples - forming a "meta-crisis" with its roots in processes deeply entrenched in society (Lane et al., 2011), and emanating from large-scale complex adaptive systems so strongly interlinked that they are hard to even define and delimit. This has made our lack of understanding of such systems simultaneously more obvious and threatening, an issue further amplified by empirical developments brought about by new information and communication technology. In response to this, a substrate of semi-congruent critiques and new ideas - the former generally more articulated than the latter - are emerging in a number of major disciplines facing similar challenges, but still without the theoretical foundation needed to align and direct this substrate across disciplinary boundaries. The first part of the thesis attempts to develop such an abstraction by departing from the nature of the large-scale complex systems, concluding that the theoretical crises are founded in common difficulties in approaching the complexity of the systems under study, and attempts to provide an understanding of the challenges related to these kind of complex systems: it may be uncontroversial to suggest that the systems are complex, but it remains unclear exactly what this entails. Based on this understanding, the second part aims to show how a synthesis approach to this type of systems could look by bringing together a number of different research strands facing challenges emanating from such systems, with the goal of forming an integrated, empirically grounded and complexity-informed perspective on change in large-scale complex systems.

Keywords: Innovation, Complexity, Society, Transitions, Innovation Society, Technical change, EvoDevo, Generative Entrenchment, Niche Construction Theory, Exaptive Bootstrapping, Wicked Systems

List of publications

I. Claes Andersson, Anton Törnberg, Petter Törnberg "An Evolutionary Developmental Approach to Cultural Evolution", *Current Anthropology* **55**, 2 (2014).

II. Claes Andersson, Anton Törnberg, Petter Törnberg "Societal Systems: Complex or Worse?", *Futures* **63**, 145-157 (2014).

III. Anton Törnberg, Petter Törnberg "Modeling Free Social Spaces and the Diffusion of Social Mobilization", *Mobilization*, (under review).

Publications not in this thesis

Claes Andersson, Anton Törnberg, Petter Törnberg "Developing of the future: scaffolded Darwinism in societal evolution", *Behavioral and Brain Sciences* **0140-525X**, (2013).

Acknowledgements

I wish to acknowledge the support of the EU-FET grants MD (no. 284625) and INSITE (no. 271574).

I would like to thank my supervisor, Claes Andersson, for showing me that you can survive in academia as an intellectual rather than merely an academic. My brother Anton Törnberg, David Avra Lane, Kristian Lindgren, Bill Wimsatt, and Justus Uitermark, for making this thesis possible.

I also want to thank all my wonderful colleagues and friends at Physical Resource Theory at Chalmers University of Technology, at Gothenburg University, at ECLT Ca'Foscari University of Venice and at the University of Amsterdam.

The synthesis was discussed and contributed greatly to by the participants[1] at the workshops organized in Venice.

Of course, nobody, apart from myself, should be held accountable for the shortcomings of the arguments presented in this thesis.

Göteborg, October 2014
Petter Törnberg

[1] Including Manfred Laubichler, Sander van der Leeuw, John Odling-Smee, and Kevin Laland. For full list of participants, see the workshop series at www.insiteproject.org/slides/new-data/.

Contents

Chapter 1

Foreword

Those who do not move, do not notice their chains.
Rosa Luxemburg.

The secret of change is to focus all of your energy,
not on fighting the old, but on building the new.
Socrates

In my younger days - before my lust for adventure was satisfied mainly through more academic explorations - I was at one point hitchhiking through southern France. I ended up in a small self-sufficient anarchist village, hidden in the lush green hills outside Alés. I was directed by a rapid stream of southern French dialect (of course complete with the mandatory hand-waving) from a group of retirees in a nearby village, to an old forest path in the hills. After passing a stolen road sign - suspended lopsided by a rusty nail in an old pine-tree - proclaiming that I was now leaving France, the village revealed itself in a small verdant valley. The settlement was built on the remains of an old farming town, whose fate had been sealed by the development of modern large-scale farming machinery incompatible with its slanting rocky hillsides. The villagers of the old town had left, leaving its buildings to slowly transform into ruins.

But these ruins found new inhabitants. It was settled by a motley crew of anarchists, squatters and hippies - some of who had given up on protesting society's injustices from the inside and decided to instead start anew, and some who had simply come to seek refuge among the warm welcoming community. The hills once again grew green with vegetable gardens, and careless goats, dogs and poultry roamed the valley.

Their living was far from luxurious - one of the inherent downsides with self-sufficiency. But they had some electricity from a small solar panel on a communal shack. And their water lacked the characteristic chlorine aftertaste of the France's civic water supply as it poured through a makeshift pipe system straight from a mountain spring.

After spending a few nights in the village, learning about their way of life and how they had organized their village, I decided it was time to move on south. After leaving the village and spending a few hours airing my thumb by a local roundabout, I finally got picked up. It was a middle-aged businessman in a shiny Mercedes, with his graying hair in a professionally short cut, wearing an austere suit and the face to go with it. After a bit of polite conversation, I was invited to his house - not an uncommon occurrence for hitchhikers, however raggedy-looking.

The man lived alone in a large newly built house on the French Riviera, designed in the functionalist concrete-and-glass style so popular among people with refined tastes. He seemed to lead a life that was the goal and envy of many. When it came to money and things, he was the definition of success. But sitting in his untarnished newly remodeled kitchen, chewing a microwave-warm low-fat fish stick, he told me - a random hitchhiker he would never meet again - about how lost he felt. He had his own company. He lived alone in this big house. He met people - naturally - but it was in a sense superficial and in the different roles he had to play in work or in social life. From where he was, he didn't know where to strive: if even with all he had, he was not happy, what else could he do?

Something about the contrast between the rich life of the poor in the anarchist village, and the poverty of the businessman on the French Riviera, stuck with me. It so clearly clashed with the success stories fed to us by television and media, telling us what constitutes a good life. Still today, having gone from unwashed and raggedy vagrant to - well a not much less unwashed and raggedy - doctorate student, it begs questions about our society and the narratives that we as a world have gathered and organized around. About how quickly we buy society's stories about what life to lead - without reflecting on the infinity of opportunities before us. How did we get to this?

1.1 Unsustainable at any speed

It is becoming increasingly clear that the path that we as a society tread is leading toward the edge of a cliff - an edge set by the limits of what our nature can provide. Yet, for our society to change direction or leave the path has proven difficult to say the least. A societal organization founded on continued growth - driven by constant innovation - has spread through the world, tearing down any trade barrier through an unending bombardment of low-priced commodities.

Fundamental in what keeps us on this destructive path seems to be our consumption. Why then do we buy what we buy? If we're honest, we all know that the purpose of an expensive watch certainly is not to tell us the time accurately. When we buy a watch, we buy the dream of who we could be and who we could become. We buy a new us. Goods seem to have gone from being objects produced by people with the goal of satisfying physical needs to become something completely different. They have become subjects, seemingly enchanted with human attributes. We buy them in the hope of finding that which we truly long after: love, community, meaning and identity. Things we can really only get from other people. And we buy them with the dream of becoming who we want to be. A watch has never been advertised as merely a useful way of telling the time. It is advertised with the beautiful women that you get wearing it, or with the successful coveted man you would become. In the same way, a new kitchen is never advertised as a useful place to cook food. It is advertised with a photo of happy friends sharing a dinner. The warm sense of community you would get with that new kitchen.

But once you've bought that watch or that new kitchen, you realize that you're still the old boring you. No new friends and no new feeling of community.

But maybe if you bought those sunglasses...

It is often said that advertisement creates false needs. This is only almost true. Advertisement does not create needs, it takes real human needs and dislocates them to commodities, enchanting dead artifacts with life, making you pay for the just things that this society has taken from us - the only things you truly want - the things that money could never buy. Without this, we would never waste our time and energy on a new kitchen. A constant insatiable wish for new artifacts can only be achieved by canalizing our longings for identity, love, community and appreciation in such a way that these longings are guaranteed never to be satisfied.

You sought friendship. You bought a kitchen. You're disappointed.

At the same time, the communities that could actually satisfy these longings for communion have been dismantled - torn to pieces by increasing speeds and distances created by our technology and the individualistic ideologies that permeate them. Social interaction is in our society being reduced to passing each other in separate cars on concrete covered landscapes. We're *bowling alone* (Putnam,

2001) - but with ever newer and shinier bowling balls.

While the problems are systemic, the suggested solutions are often individualistic. Changing the world is simply a matter of *not* buying that new kitchen. But *no snowflake in an avalanche ever feels responsible*: our manic kitchen consumption is in part the manifestation of structural factors, of the dynamics of our society.

Without your graciously provided disappointments, there would be no economic growth. The stock market would collapse, leading to unemployment, starvation, chaos. There seem to be only two options: growth or collapse. So the only realistic path is to the one we're on. Towards collapse. *There is no alternative.*

The other possible venue for change, our politics - what we think of as our society's way of managing social change - has been reduced to the art of how to best prime the pump of innovation. Increased innovation and growth is presented as the only realistic solution. The only thing we can do.

At the same time, a rising number of social, ecological and economic crises make it more and more difficult to ignore the unsustainable nature of our society.

Society's response to these crises is - as always - to try to innovate its way out of them, even though they were caused by innovations. Like an alcoholic solving his hangover by a morning drink, or Slavoj Žižek's example of the recent innovation of chocolate flavored laxatives - the problem is presented as a cure.

This approach has indeed allowed a few rich countries to become seemingly more sustainable, through de-industrialization and a transition toward a service-oriented information economy. The darker, but of course necessary, type of production - and the associated disciplined, hierarchical labor and ecological pollution - is relocated to Third World locations. The richest fractions of the populations of these rich countries can buy high-tech hybrid cars to silence that gnawing feeling of guilt. Thus, a few of the rich countries can proudly proclaim that they have through their ingenuity managed to decouple pollution from economic growth.

But it is becoming increasingly clear that it is not possible to innovate ourselves out of this social and environmental crises.

The innovation solution assumes that the type of artifacts developed through innovation cascades is controlled by social values. This is simply not the case; they're controlled solely by the direction of the gradient of increasing profits. The market controls the value of an artifact and innovation follows the rationality of markets. And this is not any old rationality. This is the rationality that says that a corncob finds better use driving a fat man's car a few meters than as food for a starving child in the south. This is the rationality that says that body hair waxing for eight-year olds is good, while malaria pills for saving lives in the third world is not really worth the effort.

Automation has made us enormously effective, what took many days and workers to produce in the 19-th century can today, with the help of modern technology, be produced by a single person in the matter of just a few hours (Paulsen, 2010). This has freed enormous amounts of human time. But as society can only function if we continue working, we still have to labor and produce during the time we've won. Produce more and build more artifacts. *Innovate, innovate, innovate.* And we could indeed find plenty of good use for these added artifacts: the needs of human kind are enormous - a large part of the global population is without food, housing and medicine, and our ecosystems are collapsing. Our enormous productivity could easily provide for the basic needs of the world's population while at the same time stabilizing a failing environment.

But feeding the poor just is not a good business model. A better model is to find what new needs can be created for the people that already have food, shelter and medicine, in addition to two plasma TVs. Sustainability or ethical consideration has little to do with what is produced.

That this is the case has nothing to do with innovators and entrepreneurs being naturally evil or unethical. There are of course many innovators driven solely by socially and ethically concerns - the point is that that does not matter in a system which is built on value rather than values. A businessman who tries to produce food for the poor is not a long-lived businessman. However, a businessman who explains to you that your loneliness is in fact caused by natural body odors, which happens to be easily solved through his new super-effective and only slightly carcinogen aluminum deodorant, is significantly more likely to achieve longevity.

Profit - not human needs - is the overarching purpose of production. And the overlap between profit and human needs is, shall we say, exaggerated.

This can also be clearly seen in what products are actually produced for the rich minority that has the benefit of constituting the profitable market. These artifacts are shaped according to profit maximization, which, as opposed to what we often think, has little to do with efficiency or utility. Instead, it more often means optimizing the pace of their obsolescence. This can be seen in the research that has been spent trying to find materials that break after a specified amount of use. It can also be seen in fashion, the social mechanism that makes your perfectly well functioning clothes suddenly seem aged and obsolescent. It can be seen in potato peel-styled potato peelers, designed with the sole purpose of maximizing the chance that you accidentally throw the peeler out with the waste. From a profit perspective, these things are perfectly rational - companies naturally need to increase their profits. From any other perspective, it is an unsustainable waste of resources in a world where the scarcity of these resources is becoming more and more acute.

But this twisted form of rationality has become so natural to us that its true nature is difficult to perceive. The economic system is not only a way of organizing production and consumption of goods, it goes much deeper: it shapes people, as well as relations between people. It controls who produces what for whom. It even changes what we value and how we look at the world; what we think is possible and what is not. It tells us that changing our economic system is naïve and unrealistic, but that infinite growth on finite resources is possible and realistic. It tells us that air pollution, dwindling fresh water reserves, human and nuclear waste, destruction of rain forests and biological diversity, scarcity of natural resources, global heating and so on, is no cause for alarm - it is not like we can change anything and surely there is some expert taking care of all that. It tells us that it is not a big problem that we are using resources far beyond what our world can provide.

The strongest public argument for the continuation of this system is simple: *there is no alternative*. But this notion needs to be challenged. While fundamental change in societal systems, what some call a Great Transition (Raskin et al., 2002), is difficult to imagine - as we can only see the world in which we live - it is by no means historically rare. Things that have been considered unthinkable and unrealistic have only a few years later been seen as natural and unquestionable. Social and technological change has proven to be as rapid as it is unpredictable. Even in our lifetimes, new technologies have transformed the way we live; cellphones, Facebook and the Internet have changed the way we organize our social life. But such fundamental changes have thus far only been organized toward what grants increasing profits to their instigators. But there is not intrinsic reason for this. Perhaps such change can be directed, scaffolded, and shaped into more beneficial forms.

But the ideas of how to achieve societal change are themselves locked-in; they are affected by the same dynamics as society itself - by the same reification as much as any other commodity in post-modernist capitalism; co-opted into a fashion attires, profaning all that is holy - as Che Guevara's face looks down from a catwalk t-shirt. When ideas become commodities, they open to gentrification - transformation by the influence of the affluent. Everything may be political, but anything solid melts into air. Ideas of societal change have been left to poets and rebelling teenagers, whose ideas - while often creative and inspirational - have a limited foundation in scientifically founded understanding of how society functions. But even the traditional social sciences have few answers to give: the left-right dichotomy in politics recollects the agent-structure dichotomy of social science. But one thing is clear: new models of change - outside of traditional ones presented by either the left or right - are needed. And today, our understanding of society may be reaching the point where an intellectual debate on the construction of such models may become possible. A world where the recipes for tomorrow's soup kitchens can at least be discussed. A foundation for ideas of another world.

Chapter 2

Introduction

Increasing inequality (e.g. Piketty, 2014; Wilkinson and Pickett, 2010), climate change (e.g. Stocker et al., 2013), eco-system collapse (e.g. MEA, 2005), economic and social instability (e.g. Colander et al., 2009; Headey, 2011; Helbing, 2013; Tainter, 1990); the evidence pointing to the unsustainability of our society is mounting. Many of these problems facing us - scientifically and as citizens - emanate from large-scale complex adaptive systems such as societies and ecosystems. These systems are not only complex in themselves, but are often interlinked so strongly and in such bewildering ways that they can be hard to even define and delimit. As the crises become increasingly more pressing, our shortcomings when it comes to understanding and controlling the systems generating them grow more apparent and troublesome.

This range of interrelated crises, or "meta-crisis" (Lane, 2011), has made our lack of understanding society and the global environment simultaneously more obvious and threatening. Social science is coming under increasing pressure, not only from this mounting scale and frequency of interacting societal and environmental crises, but also from empirical developments brought about by new information and communication technology. Old theory, thought of as safe ground, is being undermined by an explosion of new data and methods for analysis, as the societal system itself is simultaneously becoming more and more complex: more interconnected, less predictable and stable, as well as more and more energy- and material intensive, with a stronger effect on ecology and climate as a result. This is unveiling deep-rooted problems when it comes to the traditional scientific approach we have taken to these types of systems.

In response to such issues, a substrate of semi-congruent critiques and new ideas are emerging in a number of major disciplines facing similar challenges - although the problems is still significantly more articulated than the solutions. While such alternative perspectives and methods are developing, they still lack much of a theoretical foundation: there is clearly a need to align and direct this substrate on an abstract level to reach across disciplinary boundaries.

The first part of this thesis attempts to develop such an abstraction by departing from the nature of the large-scale complex systems that is the focus of these disciplines, illustrating how such systems entail certain methodological challenges, linking the efforts pursued in a range of disciplines. In many ways, the theoretical crises in various disciplines are related to common difficulties in approaching the complexity of the systems under study, and attempts to provide a basis for an understanding of the challenges confronting any science working with this type of large-scale complex systems. While it is uncontroversial to suggest that the systems are complex, it remains unclear exactly what implications this entails.

Based on the understanding of the common challenges at hand, the second part aims to show an example of such a synthesis between a range of ideas for approaching this type of systems. This approach consists of the beginning of a synthetic perspective on change in this type of complex adaptive systems, bringing together a number of different research strands facing similar methodological and ontological challenges emanating from such systems. The goal is to bring together and align a range of ideas that are beginning to develop in a range of disciplines, to form a more integrated, empirically grounded and complexity-informed perspective.

Chapter 3

Complexity and Society

Panta cwrei, oudei menei. (Everything flows and nothing stays.)
Heraclitus

Fritzgerald: *"The rich are different from us."*
Hemingway: *"Yes, they have more money."*

Let us start at the beginning: what kind of system are we dealing with here? There is a broad consensus that society is complex, but what does it mean that a system is complex?

A glance at the history of complexity science may tell us something about the meaning of the term complexity, and how this rather tacit meaning has emerged. From early on, the Santa Fe Institute (SFI) came to function as a powerful actor in uniting and aligning what can today be referred to as complexity science. The SFI was the first dedicated research center for complexity science, founded in Santa Fe, New Mexico in 1984, by a group of highly influential scientists, many of which were active at the nearby Los Alamos National Laboratory, with roots in the Manhattan Project, and thereby also in the origins of scientific computing and dynamical systems theory in general (see e.g Galison, 1997). While many important ideas about complexity are of course older than the SFI, the institute came to bring together a range of ideas and methods under the common flag of complexity science, and thereby in practice also suggesting a meaning of the concept of complexity as understood by scientists, policymakers and the public.[1]

[1]This type of social process, rather than as one may think just through a scientific basis in

Individual traditions and scientists may be more or less strongly aligned with this mainstream, but anyone claiming to work with "complex systems" must relate to it in one way or the other.

While the SFI is an explicitly multidisciplinary center, it is much less methodologically diversified, focusing on formal, quantitative methods, close to natural science and quantitative social science. At the heart of this methodology lie computer simulation, which crucially brings the capability to describe the entities and interaction rules of dynamical systems so as to put it all "into motion". The typical model in this tradition has a microlevel of interacting nodes existing in a pre-defined environment. Setting up the rules and the environment, the system is allowed to play out, and the results and patterns that emerge from the often long chains of interaction are studied. This is an highly flexible methodology that made it possible to study and visualize dynamics that are inaccessible to the unaided human mind, thus making possible a systematic inquiry into emergence in dynamical systems.

This characterization of complex systems comes naturally through the method of simulation, but has also become a way of defining complexity. It has arguably gone from simply being a methodology to attaining an ontological status. This can be seen in the characterizations of complexity that can be found in the literature. Johnson (2009) defines complexity as "the study of the phenomena which emerge from a simple collection of interacting objects". Similarly, Mitchell (2009) describes a complex system as "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning and evolution". Holland (2006) agrees, but is almost even more restrictive by stating that complex systems "are systems that have a large numbers of components, often called agents, that interact and adapt or learn." There is very much in line with Joshua Epstein's understanding of complexity (see e.g. Epstein, 1996), as something that grows from the bottom-up.

All these are different descriptions of the emergence of a macro structure from the interaction of micro entities; a specific type of emergence that we may refer to as *micro-emergence*: lower level entities interact in such a way as to generate a higher level that we cannot intuitively anticipate even if we understand completely the behavior of the lower level entities. When a higher level has emerged, it can in turn function as the micro of a second level in a multi-level system where each level can be successfully studied in isolation. This is clearly

objective theoretical demarcations, is of course how disciplines tend to develop; one "cannot [...] artificially separate the[...] substantive content from [...] social behaviour" (Price, 1970) a central type of dynamics in a wide range of systems - and it has wide-ranging methodological and epistemological implications.

Emergence here can be characterized as a certain type of mass dynamics: the interaction of a multitude of entities generates an aggregated result that we are cognitively simply not equipped to handle. The chains of causation are simply too long and interwined for us to be able to grasp them, as our cognitive abilities evolved for an environment where these systems were neither as ubiquitous nor as important. We therefore need external tools, such as computer simulations, to bridge this cognitive gap and integrate the understanding into our theories of social systems.

The nature of this type of systems is often explained by complexity scientists through a fundamental distinction between complexity and complicatedness (also referred to as dynamical and structural complexity; see e.g. Érdi (2007)). These two system qualities are often juxtaposed and contrasted for the purpose of explaining what complexity science is really about (e.g. in Cilliers, 1998). A Google search for "complex vs complicated" yields a wealth of examples, and the nature of these demonstrates that this is a distinction that is perceived of as consequential and of practical relevance. The distinction is really used for explaining what complexity is by specifying something that it is not, namely complicatedness. So complexity, then, would roughly be what we intuitively think of as complexity, but minus complicatedness. That may not go a long way as a formal definition of complexity, or even as an intelligent discussion about what complexity can be argued to be, but we think it does say something about the practice of complexity science.

When opposed in this way, complicatedness is associated with top-down organization, such as a spaceship or a computer, while complexity is associated with bottom-up self-organization - like a flock of birds or a panicking crowd. While we can study the first type of systems through disassembly - reducing the spaceship into its nuts and bolts and analyzing its structure - this does not work well with systems of the latter type: studying the behavior of a single bird in isolation will tell us little of the emergence of the organization of a flock of birds. We cannot understand complex systems through the traditional scientific method of studying the parts; the behavior of the flock comes from the interactions of its components - the magic is in the relations.

Although complexity and complicatedness are clearly linked in numerous ways - both types of systems consist of clearly separable underlying entities - they still present us with two radically different sets of methodological and theoretical challenges. The fundamental change in perspective suggested by complexity science has proven highly effective in approaching a wide range of systems that have previously been difficult to handle: from flocks of birds and beehives to traffic congestion and crowd behavior (Helbing et al., 2005; Reynolds, 1987; Teodorovic et al., 2011). This micro-emergentist approach to complexity has been highly successful in providing new concepts and tools for dealing with a wide range of different systems.

So what about societal systems in this? Are they complex or complicated - are they more like a spaceship or more like a flock of birds? On the one hand, they are undeniably complicated with their array of qualitatively different and interacting entities in a multi-level organization, which is what for example systems theories seize upon in their descriptions of societal systems. Yet society is also often, and quite convincingly, argued to be a complex system in the bottom-up self-organization sense, and much of its complicated structure arises from bottom-up rather than top-down processes (e.g. Ball, 2012; Castellani and Hafferty, 2009; Sawyer, 2005). The story is very similar for ecosystems. We clearly see no reason why systems could not be both complicated and complex at the same time, both society and ecosystems seem to constitute excellent examples of such systems.

As things stand, the mainstream of complexity science may be aware that complexity and complicatedness are distinct qualities, but complicatedness in complex systems is not seen as a fundamental problem. Complicated or not, they are complex, and that is what is seen as fundamentally important: extending mainstream complexity science to deal with them is seen as challenging, but gradual and cumulative work, often by going from simple models to more and more “realistic” ones.

In Paper I, we develop an opposing perspective, arguing that adding complicatedness to complex systems in fact does not only mean a quantitative difference, and that, consequently, adding more of the same methods used to study complex systems will not be enough. Instead, complexity and complicatedness interact, forming an emergent third category of systems, qualitatively different both from complex and complicated systems. This third type of system is referred to as *wicked systems*, in reference to Churchman (1967) concept of *wicked problems*. Wicked systems are not a type of complex systems, but a type of system where complexity is mixed with complicatedness, yielding an emergent quality - wickedness - to which neither complexity science, systems approaches, analytical models or combinations between them lend themselves very well. In other words, society is not a complex system, at least not in the mainstream micro-emergent sense.

Attempts at ignoring the complicatedness of society, regarding it solely as

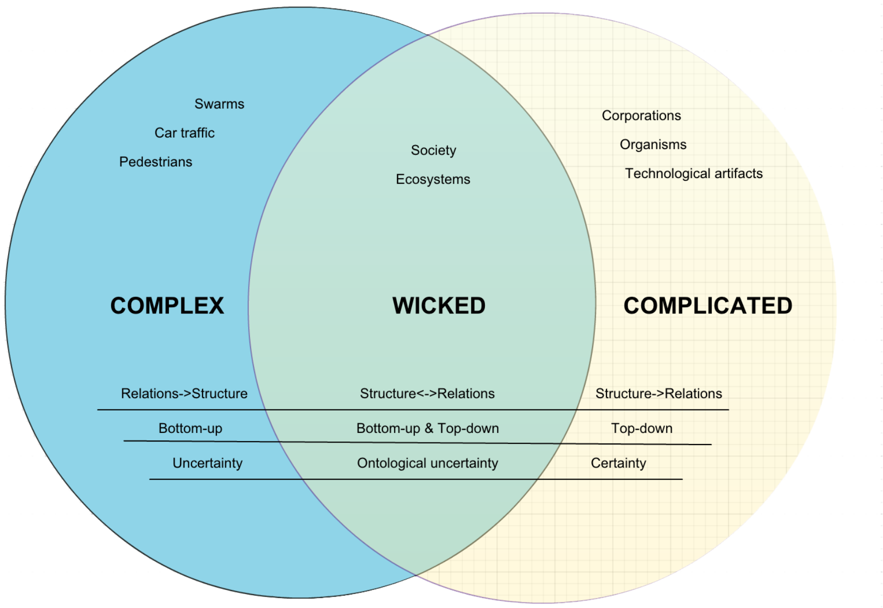

Figure 3.1: *A conceptual graph illustrating the relation between complex, complicated and wicked, as well as some example systems and properties. The diagram also serves to provide a metaphor: in the same way as the blue and yellow color in the diagram blend to create green, complexity and complicatedness mix - creating something qualitatively different.*

the same type of complex system as a flock of birds, rather quickly runs into problems. One issue that this perspective on complexity faces is that the micro entities - i.e. humans - themselves are highly complex systems, with both individual agency and the ability to instill agency into collective organizations. Social movements, professions and NGO's are all examples of macro entities that in turn have agency and that can interact both with each other and with underlying elements. Humans have the cognitive ability to interpret and describe structures, and to internally form ontologies and narratives based on an interaction with reality, and act upon those constructions. The same thing goes for collective organizations. This means that there is a presence of other types of causation than the micro-micro interaction present in micro-emergent systems: top-down causation, horizontal causation, and causation in all kinds of directions are fundamental to social systems. Such interaction in turn leads to a range of types of emergence that cannot be described as a micro-emergence. This is the complicatedness of society in action. While micro-emergence of course can be constitutive of higher order entities, higher order entities can also be the emergent product of interactions at their own levels or across levels. In other words, society is certainly complex, but it is also structurally complicated: it has a complicated set of emergent levels interacting in complex ways. The question is to what extent this poses a problem for the application of complexity theory on societal systems.

3.1 Poor Decomposability - Ontological Uncertainty and Chaos

We touched briefly on the existence of important similarities between complicated and complex systems, which turn out to be central to showing what distinguishes wicked systems from both. A crucial similarity is that they are both structured into a nested hierarchies, with each level forming the building blocks for the next: this is what allows the systems to be reduced downward into distinguishable subsystems (Simon, 1962). With wicked systems, we are not as fortunate; while they are far from homogeneous, they are in general not decomposable into stable subsystems.

A fundamental difference between complex and complicated systems is the mode of reduction: complicated systems are structured in such a manner that reduction can be done relatively easily, putting the focus primarily on the attributes of the components of the underlying level, while in complex systems the reduction are much less ordered - requiring a more relational focus. Due to the multitude of relations and interactions, complex systems have mass dynamics that are impossible to predict in detail. While this is an important difference, the similarity, that both approximate a nested hierarchical system structure, has profound implications: at each new level we can reduce both complexity and complicatedness back down to manageable levels again, and this is what allows us to construct systems that, taken as wholes, are mindbogglingly complicated; in engineering as well as in biological development. The parts of such a system can be improved independently, with respect to identifiable functions, as long as those functions are retained. For example, it is straightforward to replace the engine of a car with another engine with the same function, but, say, an improved fuel economy. In fact you can do anything to a component as long as you do not alter its interface (see e.g. "sandwiched emergence": Lane 2006; Villani et al. 2014; and "generative entrenchment": Wimsatt 2001).

That both complicated and complex systems are organized into nested hierarchies is no accident. This similarity stems from a shared developmental history of the systems: they are both in some ways selected for top-level functionality.

Selection for top-level functionality often yields hierarchical systems with near-decomposable levels (such as engineered artifacts or organisms) since such an organization increases evolutionary adaptability (Simon, 2002; Wimsatt, 1974). Hierarchical systems are simply more evolutionarily flexible: by recombining the elements and interactions of a level, a new higher-level entity can be formed.

Wicked systems do not share this developmental history, as they are generally not adaptive or lack pressure for top-level functionality. This implies that the constituents of wicked systems constantly try to outsmart one-another, reaping their own benefits, reacting to threats from other constituents. They constantly enter into new constellations, dissolve old constellations, and react to the immediate situation around them. What we get is a situation where complicated organization and complex dynamics is in a constant state of re-negotiation, constantly challenging any settlement of the system into a level hierarchy, constantly facing the system with qualitative novelty that other components have to react to.

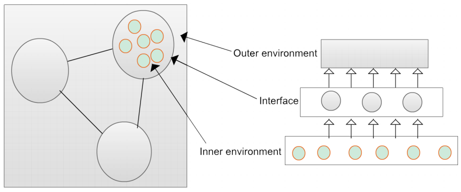

Figure 3.2: *A near-decomposable system, conceptually illustrated in two ways. Because of time scale separation, the outer environment can be regarded as static, and the inner can be similarly disregarded.*

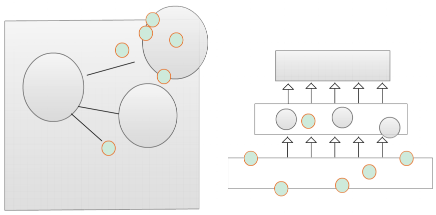

Figure 3.3: *A poorly decomposable system. Because of lack of clear system demarcations and time scale separation, it can be unclear what outer and inner environment would even mean.*

Organization into nested hierarchies also brings with it the possibility to study the systems formally "in the short run" (Simon, 1962). The meaning of short run here is a time scale is long enough for interesting dynamics to occur, but short enough for the assumptions about the interfaces to remain valid. Each organizational level brings with it some separation of time scales, implying that the ontology of the system level will be relatively fixed. The greater the separation of scales between the internal and the external environment, the greater will the difference in size and speed of the dynamics on these two levels be, and the more generous will the short run be; i.e. the more interesting things will have time to happen. Fixed ontologies allow one to specify meaningful quantitative measures from which to study the system; without such measures, only qualitative descriptions of transforming ontologies remain. This is where we are forced to operate when working with wicked systems, as they will continuously change in a qualitative way, falsifying model assumptions as soon as they are made.

This type of change is exceptionally difficult to study, even compared to complex and chaotic systems. For example, weather systems, while infamous for their unpredictability, are only quantitatively chaotic: on the relevant time-scale for weather prediction, they are ontologically fixed. The weather systems can take any from a finite set of forms and the chaos is only in relation to the degree of precision which is required in order to specify which form will exist at a point in time in the future (Byrne and Callaghan, 2013).

Clearly, however, there are many important cases where we can surely make assumptions of near-decomposability also in wicked systems, and where we thus are able to bring powerful scientific approaches to bear. For the purposes of complexity science it would seem reasonable that certain subsystems - such as crowd behavior, protein-folding, or the ceteris paribus fate of a new trait in a population - can be argued to fit this description. The dynamics of cars and people play themselves out over much shorter time scales than that on which urban systems, roads, traffic regulation and so on, change. Such phenomena are also often ephemeral, which bounds the problem even further. For example, at night the traffic jam dissipates and leaves no traces that affect tomorrow's traffic.

But what about evolutionary societal and ecological phenomena more in general? For example, what about sociotechnical transitions, evolutionary radiation events, or other wicked problems? Wicked systems in general are open systems, in which many and far-flung types of processes co-exist, co-evolve and have an impact on each other on overlapping timescales and levels of organization. They involve discontinuous, qualitative change as well as cascade effects (e.g. Lane, 2011) whereby change strongly and rapidly feeds back into the conditions for further change. Such systems are, to say the least, hard to contain in a Simonean compartment with a "short run" over which, for example, transitions can be studied against the background of an unchanging external environment. The fundamental problem for complexity science in this context, and really any approach that relies on these ontological assumptions, is that there is no way of cutting wicked systems into distinct and persistent levels of organization.

Put in another way, the type of hierarchy that micro-emergence assumes does matter in wicked systems, but neither causality nor structure is restricted to the hierarchies: we have interpenetration and overlaps, as well as multi-directional causality. Simon (1962) was of course aware of the existence of such interpenetrations. Nevertheless, he assumed that there was enough hierarchical structure to make modeling possible, and thus emphasized that which falls within the hierarchies, posing that hierarchical models provide an adequate approximation. In complex and complicated systems, such interpenetrations are indeed exceptions, but in wicked systems, they are the norm.

Wicked systems are in a constant state of flux, with only temporary stability, resulting from the interplay of a variety of counteracting forces - a boiling pot of change where each shape and structure seems to evolve as quickly as it dissolves. Discernible structures appear and some may be highly persistent while other are as quick to vanish again. Gradual quantitative change, where the entities functionalities or interactions slowly evolve, is ubiquitous, but it gradually lays the foundation for more fundamental transitions to occur: rapid qualitative change, where the very nature of the entity itself gets transformed - quantitative change becomes qualitative (Carneiro, 2000). Its demarcation lines and defining features dissolve, implying constant transformation and what Lane and Maxfield (2005) refer to as ontological uncertainty.

While this characterization of wicked systems might be new from a complex system point of view, it is far older as a description of society. This description is in fact similar to how society has been described by some social scientific authors going back to Heraclitus, 500 years BCE. It has since been repeated and developed by a range of authors, such as Goethe (in his critic of the *Gestalt* concept: "we will discover that nothing in them is permanent, nothing is at rest or defined - everything is in a flux of continual motion", Goethe 1807). Marx and Engels' materialist dialectics, of course building - and 'turning on its head' - Hegalian dialectics, was based on similar foundations (Engels, 1877, 1954). Ideas further developed in Bhaskar's critical realism (Bhaskar, 2013a,b), into which other authors added a complexity-informed understanding (see e.g. Byrne and Callaghan, 2013; Castellani and Hafferty, 2009; Cilliers, 2005). These perspectives have much in common with an understanding of wicked systems.

More broadly speaking, the wicked perspective relates in many ways to postmodern theory, which represents a major vehicle for critique against the potential of formal approaches to deal with precisely what we describe as wicked systems (Cilliers, 1998). While the critical perspective of postmodernist theory is well-developed, the constructive suggestions for alternative approaches are much less so. Rather than aiming to provide a different objective analysis, it has focused on critiquing the very idea of pursuing objective analysis, with the result of being widely seen as unconstructive. Postmodernism is very widely represented in the social sciences and humanities, and although it is somewhat waning today, what we refer to as qualitative social science is permeated by its science critique, its analysis in terms of political power relations, and in general its distrust against the idea of an objective social science that tells us how to run the world.

The result is, besides being widely seen as unconstructive, that it is even worse equipped for dealing with this new profusion of data than the theory that it criticizes. This does not mean that theory in this broad category has nothing to offer, but it does mean that, as it stands, it does not emerge as a contender for building something new. Our analysis is influenced by postmodern ideas, but it is also in reaction against the failure of postmodern critique to be constructive.

Assumptions of decomposability are so deeply embedded in our scientific work that wicked systems have not only methodological implications, but implications for the philosophical foundations of science itself. Leaning somewhat on the social scientific literature described above, we will now explore some of the implications for how to scientifically approach societal systems (the focus here is on societal systems, but to certain degree applies more broadly to wicked systems.)

3.2 Boundaries of Knowledge

What we have thus far discussed about wicked systems is that they are under constant qualitative change and ontological uncertainty (Lane, 2011). This relates to another of the central characteristics of systems with poor decomposability: that specifying their boundaries is highly difficult. While decomposable systems generally have clear defined boundaries, and in turn consist of distinguishable entities - the birds in a bird flock might interact in complex ways, but at least they can be distinguished as separate entities - but this is often not the case in wicked systems. As Cilliers (2001) puts it, what we call wicked systems

> have structure, embodied in the patterns of interactions between the components. Some of these structures can be stable and long lived [...], whilst others can be volatile and ephemeral. These structures are also intertwined in a complex way. We find structure on all

> scales. [...] [N]on-contiguous sub-systems could be part of many different systems simultaneously. This would mean that different systems interpenetrate each other, that they share internal organs. How does one talk of the boundary of the system under these conditions? (Cilliers, 2001)

Furthermore, since ideas of spatial continuity do not apply to these systems, one of the foundations on which we traditionally base the notion of boundaries is turned on its head. As Cilliers puts it:

> We often fall into the trap of thinking of a boundary as something that separates one thing from another. We should rather think of a boundary as something that constitutes that which is bounded. This shift will help us to see the boundary as something enabling, rather than as confining. [...] [An] implication of letting go of a spatial understanding of boundaries would be that in a critically organised system we are never far away from the boundary. If the components of the system are richly interconnected, there will always be a short route from any component to the "outside" of the system. There is thus no safe "inside" of the system, the boundary is folded in, or perhaps, the system consists of boundaries only. Everything is always interacting and interfacing with others and with the environment; the notions of "inside" and "outside" are never simple or uncontested. (Cilliers, 2001)

So not only are wicked systems under constant ongoing ontological change, but their boundaries are also far from as clear as positivist science must imagine them. In wicked systems, entity interaction - on and between all levels - is ubiquitous and central to the dynamics of the system. But since there are also relations with the surrounding environment, it is generally not obvious where the boundaries are to be drawn. It is more of a question of framing: we frame the system by describing it, but reality constrains where the frame can be drawn (Cilliers, 1998, 2001). The boundary is neither only a construction nor only a natural thing - it is a mix and an ongoing interaction between these.

This clearly has implications for how to approach wicked systems scientifically. While complex systems require radically new scientific methodologies to deal with the intricacies of relational reduction, the poor decomposability of wicked systems calls for something far more radical still - a fundamentally different epistemological and ontological perspective (Castellani and Hafferty, 2009).

The constant ontological transformation clearly implies a weaker type of knowledge claims, and Cilliers (2001) accordingly suggests a significantly less universal conception of scientific knowledge: as contextual, local and specific in time and space. This may sound postmodernist, but there is a significant difference between this and full-blown relativism. That the possibilities for prediction and description are limited does not mean that *anything goes*, as the most radical postmodernist theorists may put it; the world can be known, even if that knowledge is contextual and time limited. While this has implications for positivism, it in no way downplays the importance of scientific work. Quite the opposite: that our knowledge of a system is only local and temporary emphasizes the importance of knowing how to learn about a system (Byrne and Callaghan, 2013). It however affects how to scientifically relate to the systems under study, as Actor-Network theorist John Law (2004) puts it: "... [I]n this way of thinking the world is not a structure, something that we can map without social science charts. We might think of it instead, as a maelstrom or a tide rip".

But our scientific knowledge will not only be contextual and time-limited: because of the constant ontological transformation we have no stable ground to stand on required for a reduction of the system; if we are to be sure that the dynamics of the system is the same, we cannot represent a complex system with anything less complicated than itself (Cilliers, 2001). Since simplifications are of course necessary for any meaningful scientific work, this basically means that any representation will necessarily be flawed, and we cannot even know in which way it is flawed. Because of the unclear boundaries, we have to choose a framing - but picking a framing will always involves normative issues: we decide how and what to include and what to leave out.

To make this choice worse, we will necessarily affect the reality of the system through our choice in framing (Cilliers, 2000). Constructing a however arbitrary boundary for a system can mean that this boundary becomes more present in the system; temporary structures may gain longevity by being described. While charting the maelstrom of constant change, we sometimes help to produce momentary stability, as there is a form of continuous co-evolution between theories about systems and their reality (Law, 2004). Reality speaks to theory, but theory also speaks to reality as descriptions affect what is described. The act of generating the knowledge may affect the system under study, for example through what Merton (1968) called a self-fulfilling prophecy (think for example of Moore's law). As Law (2004) puts it, "[r]eality [...] is not independent of the apparatuses that produce reports of reality". This is also one of the main takeaways from Actor Network Theory (Latour, 1987).

That we affect society by studying it can actually be illustrated by the development of the postmodernist theory itself. The postmodernist crisis in knowledge was not caused by theory alone, but is a response to real changes in society. Again, reality has a voice in the formation of theory; it is the complexity of postmodern society that has generated the crisis of knowledge - but these changes in theory have also had important implications for that same reality. Again, the two interact and co-evolve.

The conclusion that studying a system implies making changes to it, in combination with Cilliers's notion that what we call wicked systems always have to be seen from a chosen frame of reference, results in serious ethical implications for the study of wicked systems. In formal models, this may be concealed behind computational or mathematical forms of representation, hiding the normative decisions of framing by enciphering the assumptions and normative choices in technical code (Feenberg, 1991). As Byrne and Callaghan (2013) note, there is a clear tendency for such ostensible neutrality of scientific work to serve what Gramsci called the hegemony.

An alternative proposed by several of these authors is a more explicit and active engagement with the system under study. Indeed, Cilliers (1998) focused strongly on the ethical implications of complexity theory and based on this argued that it was even unethical to engage with societal systems from the outside. He is not alone in these considerations. Gerrits (2012) argues in the context of policy interventions that it is necessary to engage with the actors who are part of the situation and take account of their respective narratives: in other words, as scientists, we need to embed ourselves in the processes, if we are to fully understand them.

For both Cilliers and Gerrits, active engagement becomes part of the process of science itself. Byrne and Callaghan (2013) go further: "good social knowledge of complex social systems is based on co-production between social scientists and the human agents in the field of investigation", arguing that this takes us beyond dialogue and into the realm of action - we should not only take part, but also take sides and take action. This is clearly an argument for action research, associated to a rather large strand of literature (e.g. Argyris et al., 1985; Byrne, 2011; Whyte, 1991).

While this argument may - perhaps righty - be seen as taking it too far, it clearly emphasizes a radically different approach to science than that which has traditionally been employed in complexity theory, and provides solid arguments that dealing with wicked systems requires us to stay close to the narratives and actors involved. This is certainly part of the success of the narrative approach to qualitative science: the flexibility of narratives allow a close proximity to reality, the stories and actors involved. Methods and perspective developed in an approach to wicked systems will need to show similar strengths.

3.3 Scientific Disciplines and Poorly Decomposable Systems

Assumptions based on decomposability are not only part of our scientific methodologies, but also of how our scientific work is organized. Such assumptions underlie the subdivision of scientific work into disciplines, into specific careers, into smaller and smaller parts. This approach relies on assumptions of decomposability of the system under study that, as we have seen, simply do not hold for wicked systems.

Wicked systems are not necessarily possible to separate into weakly interactive wholes. There is not necessarily *any* meaningful way of "carving nature at its joints": interactions go in all directions and there is little stable ground on which to build theory. Chewing off manageably sized pieces might in fact very well render the relevant dynamics inaccessible to study.

This implies a more integrated and synthetic science. It points to increased interdisciplinarity on all levels of scientific organization: from the education of the single researcher, to the organizational structure of universities. This is very much in line with the suggestions for a breakdown of the disciplinary boundaries made by the Gulbenkian Commission (1996) on the Future of the Social Sciences. It is of course not a new insight, but is certainly given more formal credence through an understanding of wicked systems.

3.4 Conclusion

While it is uncontroversial to claim that society is complex, what this actually means has remained somewhat unclear. Approaching society, the assumption from mainstream complexity science has been that societal complexity is essentially similar to the complexity of the kind of systems with which it has shown great success, such as flocks of birds. The undeniable structural complicatedness of society has been seen as merely a complicating factor: the only thing missing in the attempts to understand society is more effort and funding. This has not only been the foundation for the way that society has been approached methodologically, but also scientifically, as it has been seen as a green light for the application of the same type of positivist formal methods that have proven successful in the application on complex and complicated system.

However, the realization that complicatedness mixed with complexity forms an emergent new type of system - breaking the fundamental assumption of near-decomposability - has undermined the not only methodological, but also epistemological and ontological approach of both traditional and complexity-informed science. We have concluded that wicked systems are in many ways fundamentally different from both complex and complicated systems: (i) They are under constant ontological transformation: there can in general not be assumed that the underlying ontology is fixed; change is constantly both quantitative and qualitative. (ii) They are open and have unclear system boundaries. (iii) They are irreducible: as the ontology is under constant transformation, the system and its dynamics cannot be credibly simplified and reduced. The system itself is its own smallest fully accurate model.

We have furthermore concluded that this insight has important effects on how to do scientific work. In the words of Reed and Harvey (1992), we need a science that

> treats nature and society as if they were ontologically open and historically constituted; hierarchically structured, yet interactively complex; non-reductive and indeterminate, yet amenable to rational explanation; capable of seeing nature as a "self-organizing" enterprise without succumbing to anthropomorphism or mystifying animism.

No formal approach will in itself be enough to capture societal systems (Byrne and Callaghan, 2013), or as Cilliers (2002) puts it, the study of what we call wickedness "is not going to introduce us to a brave new world in which we will be able to control our destiny; it confronts us with the limits of human understanding." However, while the poor decomposability of wicked systems does not have postmodernist implications for *whether* we should do science, it does have carry significant implications for *how* we should do science. We know systems by defining them in terms of boundaries, but while these demarcations can be done in many ways, suggesting different framings of the same system, reality does have a saying in how they are made. This perspective accepts neither positivism nor relativism: it recognizes that our descriptions are social constructions, but also that these constructions are shaped by reality.

This disaffirms the current approach of complexity science in societal systems, which, as argued by Byrne and Callaghan (2013), has so far attempted to develop a positivist inquiry in qualitative social science that somehow encapsulates the complexity into formalisms, which Cilliers (2001) convincingly argues is impossible. Instead, a more constructive venue is argued to lie in the development of an exploratory and interpretative approach bridging the methodological gap between the quantitative and the qualitative. Essentially, we want to make structure part of the process, and have a methodology and ontology that allows for nested but interpenetrating systems with causal powers running in all directions.

While formal methods may have limited place in the study of wicked systems, bridging the quantitative-qualitative divide of course means significant methodological development. The rise of information and communication technology has produced an unprecedented wealth of qualitative data that provide rich, longitudinal detail about social relationships as they unfold. This potential of this data for social research has however remained relatively unharnessed, largely due to a divide between methodological development and social theory (Bail, 2014). While computer scientists have developed powerful new tools for automated analysis of such data, they lack the theoretical direction necessary to extract meaning. What is needed are new tools informed by social theory for studying social interaction and tracing the evolution of cultural elements over time. The type of approach to empirical data that this represents is in many ways reminiscent of simulation models applied by complexity scientists, in that they offer great flexibility, but bring with them certain rigor. Those tools however, as Hedström (2005) argues, are rarely at all connected to empirical data. Hedström refers to such models as *fictions*, and argues that models that do not engage with data have no connection to reality from which their *isomorphism* and validity can be assessed; they have no *mode of calibration* (Hedström and Åberg, 2005). Solving this central issue, bringing the mix of flexibility and rigor characteristic of simulation models to the analysis of empirical data, promises great potential: it allows us to stay close to empirical data, while at the same time not making assumptions of fixed ontology. It adds empirical rigor to qualitative descriptions, without giving way to formalities, or locking ourselves up to inflexible ontologies.

In short we conclude that an approach on wicked systems should: (i) focus on synthesis and the development of a post-disciplinary science of wicked systems; (ii) approach systems from the inside, rather than the outside; (iii) be explicit in normative issues; (iv) approach empirical data in a way that addresses the quantitative-qualitative divide.

It is with these heuristics in mind that we in the next part approach societal change.

Chapter 4

Innovation in Wicked Systems

The idea that change in natural and social systems is governed by homological principles is old and has long been an impetus for transferring ideas developed in evolutionary biology to the study of social systems. In the context of innovation we have most importantly the revitalization of evolutionary economics with "An evolutionary theory of economic change" by Nelson and Winter (1982), but also the not too dissimilar Dual-Inheritance Theory (see Mesoudi, 2011, for a review) in anthropology following Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985). Other such traditions include "memetics" which developed as an area of study following a suggestion by Dawkins (2006) and evolutionary epistemology (Campbell, 1965, 1974). This influence can be clearly seen in many of the terms and concepts used in technological innovation research, such as niches, evolutionary trajectories, fitness landscapes and so on. The methodology by which this idea has mainly been pursued is focused on agent-based simulation, and to some extent on population genetic models in evolutionary biology (that connection is even stronger in the related Dual-Inheritance Theory in anthropology; e.g. Cavalli-Sforza and Feldman 1981; Boyd and Richerson 1985).

Since the time when these influences were developed, evolutionary biology has undergone dramatic change, which has however not been reflected in how we look at social systems. Evolutionary thinking in the social sciences largely remains true to an older neo-Darwinian[1] conception of evolution. This framework rests strongly on population thinking (e.g. Mayr 1993) which in neo-Darwinism

[1]The theoretical foundation of evolutionary biology formed in the "Modern Synthesis" (1930-1950). The basic formal toolbox of neo-Darwinian theory has deeply shaped our intuition for evolutionary systems even when its formal models are not directly used.

came to be isolated as the real center piece of Darwinian thinking, modeling and explanation. Models are here formulated on a microscopic level of genes and traits and where the shaping forces are external to the evolving system itself and the logic of evolution is close to that of optimization. Counterparts in the social sciences then implement these models based on entities such as ideas, technologies and memes, sorted by selection pressures. The logic of populations with variation undergoing external selection remains a cornerstone also here. This type of methodology, with a set of nodes interacting in a fixed environment, is easily recognized as belonging to a modeling tradition based on assumptions of decomposability and clear scale separation. The question is to what degree such assumptions hold for this type of systems.

Over the past twenty years or so evolutionary biology has departed from the neo-Darwinian paradigm in important ways. While many of the elements of this recent "Extended Synthesis" (Pigliucci et al., 2010)[2] are older, the decisive factor in their recent strong ascent is a dramatically improved empirical picture of the material basis of the mechanisms that underpin evolution. A similar increase in data-availability is happening in the social sciences, but so far without corresponding impact on theory. The past two-three decades have seen an accelerating technology-driven development of techniques for empirical data gathering, analysis and storage. This has led to dramatically improved empirical availability in the social sciences and humanities. Old and cherished theories, models and views have in many cases proven to be unable to accommodate these new empirical pictures, and thus found themselves under substantial pressure.

In fact, this development is importantly impacting our notions of what terms like novelty and innovation mean. In biology, novelty used to be equated with genetic mutations with a subsequent and separate phase of spread, which is understood as a population genetic process. In the social sciences novelty was basically invention with a subsequent phase of rational adoption and spread - a passive "diffusion" process - understood using models that are similar (or even identical) to those used in biology. Older theories tend to black-box the mechanisms that are at play in the studied system - in other words they attempt to make do without data that used to be hard or impossible to obtain. Older theory also imposes strict scale separations, thus taming the wickedness of the system and allowing theory construction to be focused on separate subsystems, typically on a privileged level

[2]Including e.g. Evolutionary Developmental Biology (Arthur, 2011), Developmental Systems Theory (Oyama et al., 2003) and Niche Construction Theory (Odling-Smee et al., 2003). We use "Evolutionary Developmental" as an umbrella term for the systemic Darwinian approaches that have grown strongly in the wake of a greatly improved empirical understanding of how genotypes and phenotypes are really linked.

of organization. This led to theory that was workable under the technological and empirical conditions that existed, and that moreover shaped the very notion of what proper science really ought to be.

Today we see these black boxes coming ajar, and we see the interfaces between those separated subsystems - by now often marking the separation between entire disciplines - coming into view. This reveals many basic theoretical assumptions and models as misguided in highly consequential ways. One example is the concept of "adaptation" which is seen as a process of constrained optimization with regard to a timeless and external environment. As these subdivisions - e.g. system and environment - are challenged, terms such as adaptation come to take on new meanings. Such assumptions and separations have not only been built into the theories, but also into empirical models and methods, separating qualitative and quantitative change. They are also clearly at odds with an increasing pressure in many disciplines concerned with innovation for a move toward increased realism.

What this certainly points to is a methodological challenge, as of yet far from resolved: how do we deal with multi-level complex adaptive systems where organization scaffolds the dynamics that generates it? Methods based on incorrectly assuming decomposability and hoping for the best seem to increasingly have played out their role, but new ideas are simultaneously developing in a range of disciplines facing similar problems related to wicked systems. We believe that connecting and uniting these threads may contribute to a more coherent picture of how such systems can be approached.

4.1 A Synthetic Approach to Innovation

We will here briefly introduce our highly tentative synthetic approach to innovation in wicked systems. The main ingredients in this synthesis are:

- Technical change theory (theories such as Multi-Level Perspective, Strategic Niche Management, Transition Management, Social Construction of Technology, etc. and authors like Geels, Hughes, Schumpeter and many more)
- Exaptive bootstrapping and the theories associated to Lane et al (2009).
- Social movement theory.
- Evolutionary developmental biology (most notably Niche Construction Theory and Generative Entrenchment, that are explicitly represented.)

Our understanding of innovation is somewhat broader than how it is usually interpreted in the context of technical change: we focus not only on a contemporary context of technological development, but include earlier cultural evolution, with the goal of understanding the rise of the current sociotechnical organization. This allows us to study the development and transformations that lead to the development of the current societal organization. Furthermore, our understanding of innovation also includes the academically separate, but theoretically adjacent study of change instigated by social movements. It is clear that social movements and proponents of radical path-breaking technical innovations are under very similar challenges: they are centered on developing narratives that compete and diffuse in society, and they are up against existing normative and institutional configurations, that affect how their innovations are perceived and received. Entrepreneurs trying to push a radical path-breaking innovation are in many ways similar to activists trying to push for institutional change. They both develop in protected social spaces, until they are developed enough to take on the same interconnected and rigid incumbent structures. They both need to build up legitimacy and gather momentum, build networks and connect with influential actors. Such an innovation might be anything from a new story about how we can understand society or just a new physical artifact - in any case it will be dependent and connected with existing institutions, narratives and technologies. In both cases, its backers need to build up networks of contacts, build legitimacy, and spread their constantly transforming innovation. This motivates exploring common ground in theory and attempting synthesizing certain perspective (as exemplified by Paper III).

We begin by introducing what we refer to as exaptive bootstrapping. This theory was developed as part of the INSITE project, having the ISCOM project as its starting point (see Lane et al. 2009). As it provides motivation for and is foundational to the synthetic theory development, we will explore this in more detail.

4.2 Exaptive Bootstrapping and the Innovation Society

The Innovation Society is, on the most abstract level, a society where innovation is no longer just a means of solving problems: a society where innovation is ideologically sublimated and has become entrenched at the very heart of how society functions - where innovation becomes important in itself quite regardless of what gets innovated. On a more specific level, we use the term to denote the particular combination of ideology and physical infrastructure that incarnates our

Innovation Society today.

The basis for the Innovation Society and its ideology is the potential for innovation to become reified as a goal in its own right, and subsequently subjected to itself with the aim of improving its own function. Innovation has become a project for innovation itself. As a natural phenomenon this is an entirely new thing - it is unique to human culture. But it is not an essential feature of human culture - it has not always been that way. The idea that we can improve society and our own quality of life by innovation is characteristic of the Enlightenment and signifies a drastic shift in ideology: from the view that we ought to preserve a God-given social order to the view that that we ought to use science (in a broad sense) to understand the world and master it so as to increase our wellbeing. There are of course several sub-ideologies that propose different ways of organizing innovation to achieve such improvements in well-being - most importantly based on either bottom-up self-organization or top-down management. Neither has proven itself to be potent as solutions to the sustainability problems that we face today.

To understand the Innovation Society, we will have to look further into the relation between artifacts and human culture.

The introduction of new artifacts necessarily involves changes in new patterns of interaction among people, not only through the use of the artifacts, but also through, for example, their production, marketing and maintenance. There is an inextricable linkage between the introduction of new artifacts into a society and transformations in the social relations and organization of that society. As people's living conditions and social relations transform around the presence of the artifact, they may become incompatible with the institutional and organizational structures of the old. Structures that used to facilitate become deadweight. This is a point of conflict, where new organization may replace the old, where agency can play an important role, as the developing structures have not yet become entrenched.

For example, the introduction of a new software system in a business firm will affect how work is organized: the new technology is never fully aligned with the old way of doing things. The effects may be superficial or profound: it might just mean a different way of filing or it might mean that the whole floor of secretaries will become superfluous. A similar type of dynamics between technology and social organization applies on all levels of society. A society's institutions emerge in interaction with the artifacts and the technology of that society, through highly unpredictable feedback processes: on the small scale, a new office computer system may result in new company work processes; on a large scale, the hand-mill co-evolved into a society with feudal lords, and the steam mill into a society with industrial capitalists. The institutions that form around technologies need to be in a sense compatible with the technology with which they interact: when institutions become misaligned with the artifacts underlying them, instabilities occur, creating the opportunity for social and technological change. As the rapid progress of artifact innovation continues, such societal instabilities are continually sparked on all levels of society. Societal structures effective in harnessing the possibilities of available artifacts gradually turn into shackles as the artifacts continue to evolve. The breakdown of structure leads to an 'era of ferment', where a set of alternatives are competing openly for the development of new structures co-evolving with the development of new technology.

Such feedback process of co-evolution results in unpredictable social and technological transformation, making it highly difficult to achieve intended social effects through technological development. But such technological change is in any case the exception: artifacts are generally not evaluated on the basis of the transformative effects they will have on societal structure, they are solely evaluated for their perceived benefits for the individual agent that decides whether to purchase it. The impact on social relations is here an unintended consequence. It is this type of atomistically individualist evaluation processes that decides the value of new artifacts; it is the what we refer to when we say *the market* - a central actor in our current innovation society. Atomistic rationality has taken over a larger and larger part of what used to be part of the realm of political decisions, while politics is increasingly left to priming the pump of innovation. Progress is seen as inevitable, whatever it may entail (Ellul, 1967).

The stability of this system is based on competition on all levels. Competition out-crowds everything but more innovation. Any attempts to subordinate innovation to other values, like cultural enrichment or social justice, are made impossible by competition at the level of individuals, firms and national economies. Competition dooms any potential Samaritans to failure, which at the national level - which ostensibly has some level of political play - would translate into economic decline and social chaos. This in practice undermines any attempt at going against the stream, except on the global level where necessary organizational structures are largely lacking.

As we have seen, the causal arrows between innovation and organizational transformation go both ways: new innovations change our organizations, and changing organization affects what artifacts are produced. This means that a feedback dynamic is present (Lane, 2011). We have the formation of innovation cascades, linking the generation of new artifact types, organizational transformations and new attributions of functionality. According to Lane et al. (2009), the positive feedback dynamic works as follows:

1. New artifact types are designed to achieve some particular attribution of functionality.
2. Organizational transformations are constructed to proliferate the use of tokens of the new type.
3. Novel patterns of human interaction emerge around these artifacts in use.
4. New attributions of functionality are generated - by participants or observers - to describe what the participants in these interactions are obtaining or might obtain from them.
5. New artifacts are conceived and designed to instantiate the new attributed functionality.

As the negative side effects of these innovations are neither expected nor evaluated for, they accumulate over time, resulting in crisis (Sveiby et al., 2009). How does society respond to these crises? Because of the limitations set by competition, political decisions are mainly limited to attempting to steer and encourage the right type of innovations - but the dynamics of unpredictable cascades makes this type of control highly precarious. In a process that seems to perhaps exemplify what Hegel called the irony of history, even the most well meaning attempt at solving a crisis tends to sooner or later generate a new crisis. But for a society based on market-based decision-making through innovation, this is the only solution available. The market responds to opportunities to remediate the consequences that innovation cascades may generate, but it is becoming increasingly difficult to ignore that the market is not very efficient at this. This again relates to the dynamics of market decisions and its constant guiding light of economic value. What is worse, as these suggested solutions are not evaluated with regards to resilience or sustainability, they often take the form of going from the frying pan to the fire: like the alcoholic curing a hangover, society tries to solve its problems by applying more of what caused the problems.

An illustrating example of this is the current obesity epidemic in large parts of the western world. Technological innovations in agriculture, mainly in the form of using finite resources to replace labor and access to soil, produced a surplus of cheap calories. To increase returns, these products were increasingly processed in a co-evolution with changing patterns of consumption, which in turn interacted with changing values in society. The detrimental health effects of the set of western food that evolved from this are well-documented (see e.g Pollan, 2008). But the market's response to these issues were not to stop marketing of products that are clearly unfit for human consumption, but rather to take (the more profitable) route of technological development in primarily the diet and pharmaceutical industries. While these have been enormously profitable, they have also had basically no effect on the obesity epidemic.

The central role of innovation in contemporary society means that the processes of changing institutions occur much more swiftly today. Creative destruction is more and more swiftly accepted, as other values than value are less and less valued.

Lane et al. (2011) summarizes the Innovation Society and its ideology as follows:

> Our society's dependence on innovation cascades is expressed in, and sustained by, an increasingly widespread way of thinking, which we will term the Innovation Society ideology. This ideology underlies almost all current discourse about business strategy and governmental policy. The following four propositions form its central core: (1) the principal aim of policy is sustained economic growth, interpreted as a steady increase in GDP; (2) the engine of this growth is innovation, interpreted as the creation of new kinds of artifacts; (3) Which new kinds of artifacts have value is decided by the market; (4) the price to pay for not innovating, or for subordinating innovation to other values, like cultural enrichment or social justice is prohibitively high: competition, at the level of firms and of national economies, dooms dawdlers to failure, which translates into economic decline and social chaos.

4.3 Niche Construction Theory

Niche-Construction Theory challenges the idea that "organisms adapt to their environment, never vice versa" (Williams, 1992) by emphasizing how organisms affect their environment (Odling-Smee et al., 2003). Any organism living and interacting with an environment will naturally affect its surroundings: it absorbs energy and resources and emits detritus; it constructs artifacts and finally dies, and through such actions modifies at least parts of the environment. Such modifications will naturally become part of the natural selection pressure of organisms living in the environment, including the organism that initiated the modifications. In this sense, organisms are influencing their own evolution by creating the conditions of that evolution. Odling-Smee (1988) introduced the term *niche construction* for this phenomenon, observing that it has wide implications for evolutionary theory since it profoundly transforms the conception of natural selection: the perspective changes to viewing evolutionary change as "reciprocally caused" (Laland et al., 2011). The process is furthermore very general, to the extent that it is exhibited by all living organisms (Odling-Smee et al., 2003). Despite of this, the field has only quite recently become an area of study within evolutionary theory (Laland and Brown, 2006).

Much of the importance of the niche construction concept emanates from the fact that it replaces a simple adaptation perspective with a framework focusing on co-evolution between organism and environment, where feedback and interaction takes the center stage. There are many evolutionary effects like these that niche construction can result in, many of which have been uncovered through modeling or mathematical analysis. Some of these dynamics include momentum effects (continued evolution despite that the selection has stopped or reversed), the generation of time lags in response to selection, inertia effects (no evolution despite selection pressure), exacerbation or amelioration of competition, affecting co-evolution and the likelihood of coexistance, opposite responses to selection, and sudden catastrophic responses to selection. (Krakauer et al., 2009; Kylafis and Loreau, 2011; Laland et al., 1996, 2001; Robertson, 1991). (See Laland et al. 2014 and the references given therein for a more thorough listing of the effects on evolutionary dynamics.)

Niche Construction Theory implies a very concrete challenge of the treatment of natural evolution as a decomposable system, both in modeling and in the scientific organization. Population genetic models typically view evolution as an adaptation to a fixed environment that is external to the process, and based on similar assumptions the study of biology is subdivided into disciplines, for example treating ecology and evolution as two separate subjects. As Niche Construction Theory shows, this is based on problematic assumptions about evolution: it treats a wicked system as decomposable.

Niche Construction Theory is a highly general idea, and as a general idea it is perhaps not as new as its biological incarnation: similar ideas have long been pursued in the social sciences. But on the other hand, this congruency also opens up paths for cross-disciplinary learning about such processes. Niche Construction Theory has been applied in the context of cultural evolution (e.g. Laland and O'Brien, 2011; Laland et al., 2001), but the focus has been on the effect of culture as a constructed niche on biology. While this is of great interest, Niche Construction is also useful as a perspective on cultural dynamics itself: the same delineation problem that applies between organism and environment applies also between culture and environment.

4.4 Generative Entrenchment

Intuitively, Generative Entrenchment can be understood from the simple fact that "trying to rebuild foundations after we have already constructed an edifice upon them is demanding and dangerous work" (Wimsatt, 1999), or put more generally: more entrenched system elements tend to be more evolutionarily conservative (Rasmussen, 1987; Wimsatt, 1986). Change in a component that underlies other components results in changes also higher up in the structure, causing a cascade of changes. The change in the underlying component must be evaluated not only with regard to the change itself, but also to the net effects of all cascading changes, and these must be beneficial for the change to be adaptive. In other words, the further down in the foundation the element is, the higher the risk that changes will cause irreparable damage to higher-level structures. However simple, this fact has large consequences on the system dynamics and represents an important generator of complex organization (Wimsatt, 2013).

Let us clarify this using individual learning as an example. We acquire culture in a process of enculturation, which exhibits an entangled mixture between cultural and physiological development: through physiological development in our cognitive skills including speech and motor skills, through training and mentoring in our more culturally specific skills. Developmental dependencies affect essentially all of our skills, including writing, reading, mathematical skills, and the various subject matters we learn in school, as well as in our social skills, and the various practical skills from riding a bike to using complex tools. Entrenchment here is the process through which the earlier skills that we acquire are built upon and presupposed in acquiring the later skills, for which the earlier skills become essential. This hierarchical organization of knowledge is highly economic as it re-uses learned elements and minimizes the number of elements that we will need to learn. It also makes learning more robust and flexible. The most general and basic knowledge is learned first (e.g. the alphabet, writing, simple arithmetics and so on) and for each step we take in the learning process new doors are opened up since what we have learned will allow us to learn new and more derived things. With such a hierarchical arrangement of knowledge we also do not have to retrace all the way to the bottom if we want to learn something else; we just retrace to an earlier intermediate point and chose another direction from there (e.g. at the level of college studies). But the flexibility that we gain by this arrangement is not perfect of course: the hierarchical organization enables and constrains our options. The constraining effect of the most basic levels is actually probably so strong that we even have problems imagining what sort of things that would have been possible if they were different. This includes not only tools such as writing and mathematics but also basic notions of what is valuable, virtuous and bad. We may certainly "think outside of the box", but the further down the hierarchy we go the harder it gets, and indeed the more unpredictable the outcomes if we really do it.

In this way, entrenchment constitutes a fundamental link between structure and dynamics of evolutionary systems, showing how structure limits, scaffolds and transforms change. Interesting dynamic phenomena, such as stasis and rapid transformation, adaptability and hierarchical structures, are interlinked through entrenchment. Entrenchment is fundamentally the reason why history matters, since the order of evolution of elements will often be reflected in the structure of these dependencies. Structure limits adaptation; stasis is adaptation limited by structure; rapid change is cascades of structural transformation.

4.5 Transition Theory and Technical Change

The multi-level perspective focuses on sociotechnical transitions, and on what conditions need to apply for fundamental transitions to take place (see Geels, 2002, 2011; Geels and Schot, 2007; Markard et al., 2012). This theory distinguishes three analytical levels: niches, socio-technical regimes and exogenous socio-technical landscapes. Niches constitute the micro level where radical innovations are generated and grow. They provide protective spaces for new path-breaking radical alternative technologies to protect them from the normal selection environment. Regimes consist of rules in the form of the prevailing norms, values, technologies, standards and infrastructure embedded in the elements within the socio-technical regime. These rules guide the involved actors and tend to limit patterns of behavior and lead to lock-in and path-dependency for technological development. Hence, socio-technical regimes are functionally similar to what Kuhn (1962) called paradigms, as their function is to "create stability and guide innovative activity towards incremental improvements along trajectories" (Geels, 2002). The socio-technical landscape refers to the wider macro-level technology-external context that includes both material and social factors, forming a context and deep structural trends for both the regime and niches.

Together, these analytically separated levels constitute a socio-technical system and socio-technical transitions are understood as regime changes, which are the result of multi-dimensional processes and interactions within and between these levels. In short, Geels and Schot (2007) describe the relation between the different levels as a *nested hierarchy*, meaning that the socio-technical regimes are embedded within landscapes and niches within regimes. These components and sub-systems depend on each other, and this interdependency functions as an obstacle for the emergence of new technology (Geels, 2004). Hence, this basic structure tends to lead to changes within the regime being incremental and path-dependent, leading to lock-in processes. While some new innovations are well-adapted and can be incorporated within the system, others are not compatible with the existing regime and therefore have difficulties breaking through.

The key-point of this framework is that technical transitions occur when the interplay and linkages within and between dynamics at the different levels become connected, link up and reinforce each other. A necessary condition for radical technical transitions to occur is the combination of the rise of a strong socio-technical alternative fostered in niches together with an opening in the selection environment within the socio-technical regime. If tensions build up in the existing regime level, this results in *cracks* or *windows of opportunity*, which possibly enable breakthroughs of new radical novelties (Geels, 2006b).

These processes can lead to the emergence of unexpected and unforeseeable consequences, such as when the breakthrough of a specific artifact, or small changes in the landscape or regime level, lead to a cascade of new innovations, due to processes linking up and reinforcing each other. This means that changes in one element of the network can trigger changes in another element and even lead to radical transformation in the entire structure. Under certain circumstances, a wealth of innovations can grow in niches under the surface, unable to break through since the regime is stable. In these cases, a small crack can lead to "an era of ferment" when these hidden innovations manage to "hit the surface". Other well-known phenomena within socio-technical systems are the above-mentioned lock-in processes and path-dependency, which are central notions relevant to understand the stability and *dynamic rigidity* (Geels, 2004) in socio-technical systems as well as the difficulty to change established regimes.

Following this, transitions cannot be explained by *constant-cause* explanations (Geels and Schot, 2007). The co-evolution approach on which the multi-level perspective is based focuses on evolutionary causality or "circular causality" (Geels, 2005), meaning that multiple dynamics within and between elements of socio-technical systems interact in feedback-loops; they co-evolve. "The co-

construction process of new innovations is non-linear and uncertain" (Geels, 2006a) and "consists of multiple dynamics, interactions, co-evolution, feedback, seamless webs and emerging linkages between heterogeneous elements" (Geels, 2004). Hereby, multi-level perspective moves focus from simple causality in transitions and system innovations. There is no simple 'cause' or 'driver' but rather "processes at multiple dimensions and levels simultaneously" and transitions occur "when these processes link up and reinforce each other" (Geels, 2005).

Sociotechnical regimes in turn fit into larger structures of interconnected sociotechnical systems, which Grübler (2003) refers to as technical clusters. There is in this way in a sense a self-similarity in the network structure: dense areas in the network can in turn be seen as nodes of a higher-level network. Parts of the cultural machinery that are more entrenched than others form a tightly knit core of the cultural system. The collapse of such large-scale technical clusters is one way of seeing important societal transition, such as the transition to industrialism. The core technologies of the system are changed, and the new developing technologies and institutional structures are designed around this new core. Such transitions bring with them fundamental institutional changes, such as new ways of organizing labor, as was clearly the case in relation to industrialism.

New sociotechnical systems can develop into stable regimes as part of a previous technical paradigm, simply by being competitive despite lack of support from a coherent technical cluster. They can through this contribute to forming scaffolding structures, facilitating the development of other technologies, constituting the seed of a new cluster - in a feedback process that can result in a rapid large-scale transition. Such interdependencies and amplifying phenomena between sociotechnical systems can be strongly non-linear and are in general highly difficult to anticipate.

4.6 Returning to the Innovation Society

Let us now turn this framework toward the system that motivated its development. The Innovation Society does not really break with old traditions as much as one may think when it comes to the fundamental dynamics of innovation. Basically the same mechanisms of innovation are at play. But it does do something highly powerful and peculiar from a natural historical point of view. In the innovation society, the natural growth has in a deep sense turned cancerous: it is no longer motivated, controlled or limited by needs, but has become a goal in itself. Innovation is no longer simply a process that emerges as we exercise our cultural strategies - but has become something that we consciously pursue, ideologically look upon as virtuous, and that we have become dependent upon.

This positive feedback innovation dynamics have become ever more important in the organization and ideology of our society. Just like species collectively constructing a functional biotope adapted for biological life, our society has become formed into a perfect habitat for the development and marketing of new artifacts. Through a set of evolving organizational forms - such as organizations for design and engineering of new innovations, as well as the adverting and marketing industry identifying and creating new demand - the cycle of innovation has sped up. The cascades of change running through society - through its foilage rather than its trunks - are because of this larger and more frequent.

The structures and forms of organization that this niche of perpetual artifact production has resulted in have themselves become further and further entrenched in society, to an extent that the innovation engine today itself is rooted into the core of the sociotechnical cluster that constitutes our society. It has formed a regime that has become necessary for the functioning and stability of the sociotechnical system itself. While we have become dependent on this core, it provides a rather paradoxical stability: we have become locked-in to state of constant explosive change. Our blind pursuit of change and novelty means that society is exposed to the danger of being undermined by the mass of unforeseen side effects that we cannot avoid due to ontological uncertainty (Lane and Maxfield, 2005).

This constant innovation - without aim or goals; without any continuous evaluation; without social considerations; without contact with the resources on which it depends - will inherently lead to crises. These are endogenous to our way of organizing innovation processes: a system based on competition in innovation and marketing efficiency will naturally be unable to develop long-term resilience and sustainability (c.f. Tainter, 1990). As our society becomes more efficient, it also becomes less resilient, as it become more interlinked and interdependent, the crises become increasingly large-scale (Helbing, 2013).

If the meta-crisis is indeed endogenous to our societal organization (Lane et al., 2009), the available societal control mechanisms seem inadequate to provide a necessary response. To the extent that policymaking is supported by science at all, it preferentially relies on the type of formal quantitative models epitomized by neoclassical economic theory, which notably places primacy on the microlevel and on economic value as the prime mover of society. But in the wake of this meta-crisis, which has neither been predicted nor hindered by our current understanding, there is a widespread sentiment that we must bring about a type of societal change that is outside the scope of this type of models, such as broadening the range of factors that affect the direction of society: from a primacy of economic values to the inclusion of also societal and environmental values; from a reductionist and economic-value-centered view to a more holistic and inclusive one.

Innovation is by definition needed to solve the metacrisis, but at the same time, it is also what caused the crisis - innovation as constituted by our current processes of innovation. The necessary innovations and social transformations needed to solve the metacrisis is unlikely to be generated by the same structures that caused it.

An alternative regime for innovation is thus needed. But as we have seen, there appears to be no off-the-shelf approaches for organizing innovation in ways that lead to a sustainable path into the future. The meta-perspective of viewing the structures and processes of innovation as regimes - constructing niches and themselves becoming entrenched - was useful to understanding the problems we face, and can perhaps be similarly useful in finding a solution to them. New forms of innovation and production, unattached to the structures of the current regime of innovation and instead belonging to a new cluster of societal organization, can contribute to the formation of scaffolding structures facilitating the development of additional new forms of organization. Communication technology are central in the development of such processes, as they constitute an unprecedentedly versatile tool for creating scaffolding structures for new forms of decentralized collaboration - a central foundation for the development of new innovation processes.

For such processes to develop, we need to find protected spaces outside both conventional politics and the market, where such alternative processes can grow, shielded from the existing regime of innovation. Once developed, such innovative forms of processes can lead to a bootstrapping process, forming a new framework for the organization of innovation processes, allowing for new forms of evaluation and participation. Such processes can happen as fast as fast as they are unpredictable - with change on the fringe quickly bootstrapping into profound societal transformation.

Finding spaces and community for alternatives to grow does not have to mean moving to an anarchistic village. But it does mean finding new stories, outside dreams of new kitchens. Stories focused on building the new; able to conjure new spectres, to haunt the dreams of the old.

Finding spaces and community for alternatives to grow does not have to mean moving to an anarchistic village. But it does mean finding new stories, outside dreams of new kitchens. Stories focused on building the new; able to conjure new spectres, to haunt the dreams of the old.