A new perspective on innovation

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Deliverable 3.2

1. Understanding the Innovation Society

The concept of the Innovation Society is used by Lane et al. (D 2.2) to describe our current society as based on a particular way of organizing innovation, with an associated Innovation Society Ideology that motivates this organization. The INSITE project problematizes the effects that this Innovation Society has on sustainability, and a central aim is to build a theoretical understanding of how innovation works that allows us to understand and devise solutions to such problems..

We have engaged in this work in several ways, most importantly we have: (i) performed literature studies; (ii) carried out case studies; (iii) organized workshops on the topic of innovation theory, and (iv), integrated results of research carried out as part of the related MD project[1]. This introduction and collection of texts reflects these activities and draws some conclusions from them. The chapters include texts of our own production as well as pertaining papers submitted by associated researchers that have participated in our workshops.

The Innovation Society is on the most abstract level a society where innovation is no longer just a means of solving problems: a state 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. Lane et al. (2011) describe our 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

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[1] Emergence by Design; FP7 FET Open, Contract #284625.

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.

2. Our starting point

INSITE took the theoretical platform developed under the ISCOM[2] project as its starting point (see Lane et al. 2009). From there we have expanded our theoretical foundation in several ways, incorporating new concepts and models. The basic observation is that innovation feeds upon itself: innovation generates more innovation. The underlying organization of societal systems (and, as we shall see, many other complex adaptive systems) is conceptualized as networked, and in our conception[3] of a networked society we bring out a number of features that are central to our concerns. The first is that the network consists of both Agents and Artifacts; we refer to it as an Agent-Artifact space (Lane et al. 1996). The central point here is that changes in this network have potentially global effects; cascades of transformation are generated in this network and this we see as the essence of innovation. The methodologically convenient assumption that novelty arises for some certain purpose, and then proceeds to passively "diffuse" through a network of adopters, which is otherwise commonplace in the innovation theory literature (e.g. Rogers 2010), is therefore strongly insufficient for our purposes.

In Chapter 2 (Lane 2011), innovation in this Agent-Artifact space is described as Exaptive Bootstrapping; a five-step cycle:

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.

[2] The Information Society as a Complex System; FP5 IST-2001-35505

[3] The notion that society and other complex systems can be usefully conceptualized as a network is of course commonplace and has served as the basis for a wide range of models and theories.

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

This sequence describes a bootstrapping process: the 1st and the 5th steps are identical. Steps 2 and 3 depict how novelty does not simply enter the overall system passively: its entry transforms the whole landscape in which it subsequently exists. This is where cascades originate. Innovations do not just solve problems, they also create problems and opportunities downstream, and they continue to do so as they encounter new factors that may not even have been present at the time when they entered the system. This is also described as a fundamental Ontological Uncertainty that besets anyone with the ambition to act in such a system (Lane and Maxfield, 2005). Step 4 represents the "exaptive" component that lies at the heart of this process. Exaptation is a concept, originally introduced by Gould and Vrba (1982) in evolutionary biology[4], that identifies the fact that an artifact (or feature of an organism or any other adapted structure) that is employed in a certain way, and that is presently favored because of its utility in that area of use, almost always can be gainfully put to other uses as well. When this happens – as it frequently does – the evolutionary history of the entity in question splits up, generating divergent future "lineages" as the artifact is now placed under two (or more) different regimens of functional requirements.

Occasionally – throughout human history and pre-history – innovation has taken off in dramatic ways, while at other times it has entered prolonged locked-in states with little change. But even when innovation takes off, not all parts of societal systems necessarily change, and that is just as important for understanding how innovation works. In fact, modern society can just as easily (and relevantly) be portrayed as being deeply stuck in its own tracks! The contradiction here is only apparent: it is a question of understanding what directions innovation cascades take. And there is an interesting twist here too. We see the Innovation Society as something as curious as a lock-in to a state of explosive change!

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[4] Although described in detail already by Nietzsche in 1887 in a project of understanding innovation as a historical phenomenon in the context of morality (Nietzsche 1887).

The basis for the Innovation Society and its ideology is that there happens to be 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.

3. A new general approach to innovation

But let us begin with the some background. To understand how the Innovation Society works, we must understand where it comes from – we must understand innovation in a way that the Innovation Society Ideology itself – which is otherwise a main motivator for innovation research – may not readily call for (which tends to emphasize ways of boosting innovation; see above).

In a recent series of workshops at the European Center for Living Technology (Organized by INSITE), we have explored the potential of a recent connection between biology and the social sciences (e.g. Erwin and Krakauer 2004; Wimsatt and Griesemer 2007; Andersson et al. 2014), with participants from innovation research, biology, archaeology, complexity science, etc. This new potential has emerged particularly clearly with the rise of developmental theories of evolution in biology, combined with an increasing interest in multi-level complex systems where organization acts as a scaffolding structure for the dynamics that generates it (e.g., Lane et al. 2009; Byrne and Callaghan 2014). What has emerged with clarity in these workshops is that innovation researchers, developmental evolutionary biologists and complexity scientists understand each other well with a minimum of "translation"; there is a striking commonality between descriptions of historical phenomena as empirically different as the Cambrian Explosion, the emergence of automobility and cultural transitions in the Paleolithic.

The reader may interject here that the connection between biology and social science in understanding innovation is an old one; one that is even well integrated into complexity science. This is true. What we propose is a new connection – one that connects developmental evolutionary theory with approaches based on historical case studies in the social science, and that places organization rather than population thinking first (Lane et al. 2009). This does not mean that we eschew formal modeling, or even population thinking. Quite to the contrary – as we shall see, we think they are necessary, but we see them as only one tool among several tools. Let us briefly describe this "older connection" to provide a contrast with the direction that we pursue.

This older connection is widely influential in innovation research, not least through Nelson and Winter's seminal work "An Evolutionary Theory of Economic Change" (1982). These ideas are inspired by the "Universal Darwinism" movement (e.g. Dawkins 1983; Hull 1988; Nelson 2006) and the idea that Blind-Variation-Selective-Retention (often referred to simply as BVSR) is fundamental to all novelty and thereby to innovation (Campbell 1960; 1974)[5]. The methodology by which this idea has mainly been pursued is heavily 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).

This older connection is oriented towards a natural science methodology, while the new connection that we pursue is more oriented towards the narrative case study methodology, more typical of the humanities. This will seem as a step backwards to those that see formalization as a central imperative of science, but it is also seen as a step towards more realism by others.

[5] In my opinion, Campbell's ideas have been applied much too literally and have thereby not been fairly represented in the secondary literature. Campbell was an epistemologist and his aim was not one of finding a practical model of innovation in a positivist sense. His thesis (in which he was aligned with Popper; e.g. Popper 1979) was that among Kant's four categories of novelty (analytic a priori/analytic a posteriori/synthetic a priori/synthetic a posteriori), instances of the three former must ultimately be explained as the fruits of the latter (see also Cziko 1995). His argument is not about analytic reduction of innovation to Blind-Variation-Selective-Retention, although it is often used in support of such a programme.

Moving towards more realism has become an acutely felt need in many disciplines concerned with innovation over the past decades, and because of strong empirical developments lately it is hard to see how we could ever go back to the old ways of looking at evolution and innovation.

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 a dramatically improved empirical picture in all the three "innovation fields" that we primarily deal with – archaeology, biology and innovation studies in the social sciences and humanities. Old and cherished theories, models and received views have found themselves under substantial pressure in new emerging empirical contexts.

An often-heard question today is: what do we do with all this new data? We have data that is new in both a quantitative and a qualitative sense – and we focus particularly on its novelty in the latter of these senses. Entirely new things have become possible to study empirically[6]. This is also the basis for the framing of our third INSITE workshop[7] on these topics.

Theory developed in earlier and more "data sparse" eras – and adapted to such conditions – has in many cases proven not to only be unable to accommodate these new empirical pictures; it has also been discredited by them. 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 theory tends to black-box the mechanisms that are at play in the studied system – in other words it attempts to make do without data that used to be hard or impossible to obtain. Older theory also imposes strict scale separations, which allowed theory construction to be focused on

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[6] In biology and archaeology we see in particular the addition of a whole battery of laboratory techniques (e.g.DNA analysis and improved dating methods to mention a few). In the social sciences, ICT has made data more voluminous, accessible and amenable to automatic analysis, it has allowed more systematic and microscopic data gathering possible, and it has also greatly facilitated literature searches.

[7] "New Data – Old Theories: The Future of Theorizing about Innovation in Complex Adaptive Systems" May 5-8, 2014.

quite separate subsystems, typically on a privileged level 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.

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?

4. Complex Adaptive Systems: Wicked Systems

To understand that we must ask what it means that society is a "complex adaptive system?" What do we mean by "complexity"? What do we mean by "adaptation"? The latter question has been hinted at, and will be discussed more later on. Let us now delve a little bit into the concept of "complexity" and how innovation is a phenomenon of complexity. The most basic distinction with the class of what we tend to call "complex systems" is perhaps that between structural and dynamical complexity (e.g., Erdi 2008); or, as some might say, between complicatedness and complexity. An illustrative example of the first is the space shuttle, and of the second a flock of birds (e.g. Eriksson et al. 2010). Is society more like a space shuttle, or is it more like a flock of birds? It clearly appears to partake of both of these qualities, and does not emerge as a central example of any of them. Andersson et al. (2014b) argue that the systems that we are interested in when trying to understand innovation exhibit a developmental mixture between complexity and complicatedness, and that this mixture is emergent; i.e. it is like neither. This mixed type of systems is referred to as "Wicked Systems".

The term "wicked systems" is chosen in recognition of a potentially deep connection (whose exact nature remains to be worked out) between this class of systems and what has been called

Wicked Problems. The term Wicked Problems' was first coined in management research by Horst Rittel (briefly introduced by Churchman 1967) to characterize a class of problems that failed to fit into the molds of the formal systems theoretical models that were being applied across the board at the time with considerable confidence. Just about any large-scale societal problem can in fact be confidently put into the category of wicked problems: starvation, climate change, geopolitical conflicts, social disenfranchisement, and so on. All these are problems that escape definition and where there is a constant feeling that the efficacy of proposed solutions is called into question not only with regard to feasibility and adequacy but also with regard to the risk of creating cascades of other problems that are impossible to foresee and that may be even worse than the initial problem (see also Leach et al. 2007; Scoones et al. 2007). Explicating the concept, Rittel and Webber (1973) conclude that the domain of wicked problems in social systems is vast - it includes just about any problem short of trivialities. In Churchman's (1967) words, what we do with wicked problems is to either tame them by creating “an aura of good feeling and consensus" or by “carving off a piece of the problem and finding a rational and feasible solution to this piece”; this would appear to well describe also our generalization of Wickedness. By considering Wickedness as a system quality, we generalize to also be able to speak of things like wicked dynamics, wicked phenomena and wicked systems.

How do we understand Wicked Systems? If we look at the examples proposed by Andersson et al. (2014b; see Fig 1 below) we see that the examples of Wicked Systems appear to be precisely the major examples of Complex Adaptive Systems that we find in nature. These are also the systems that the fields involved in the “new potential connection” between natural and social science that we discussed above deals with. We suspect that innovation is central to understanding Wicked Systems, and the other way around. So how do we try to understand Wicked Systems today?

Andersson et al. (2014b) map analytical methods into the same diagram in order to identify the theoretical lacuna that exists today with regard to understanding Wicked Systems and thereby innovation; see Fig. (2), arguing that narrative based historical case study must play a central role in understanding these systems. In itself this is of course not a new argument, and narrative is of course the oldest form of theorizing about social systems. There is quite a deal of literature on the concept of “narrative” and how it is important for not only “wrapping our minds around” societal systems, but also to deal with its constant state of change from innovation, re-interpretations and the potential for taking different perspectives on the same thing. There is no room here for a review of this literature, so we point the interested reader to e.g. Ragin (2009), Geels and Schot (2010), and, Lane and Maxfield (2005) and further references therein.

The reason why formal methods work poorly here is that the events and processes that we want to understand are manifested as unique historical trajectories in systems that are strongly entangled hierarchies, lacking the clear-cut compartmentalization that is otherwise central to the applicability of formal approaches. We are thereby unable to clearly identify what we can assume to be laws, parameters and variables in a model: too many things are coupled and change on similar time scales. The system tends to make up many of its own rules as it goes along (as we already mentioned as Ontological Uncertainty above). But at the same time, we absolutely need formal approaches to understand emergence and non-linearity in complex systems: we have no reliable intuition for the behavior of large numbers of entities interacting in parallel. This creates a major methodological challenge.

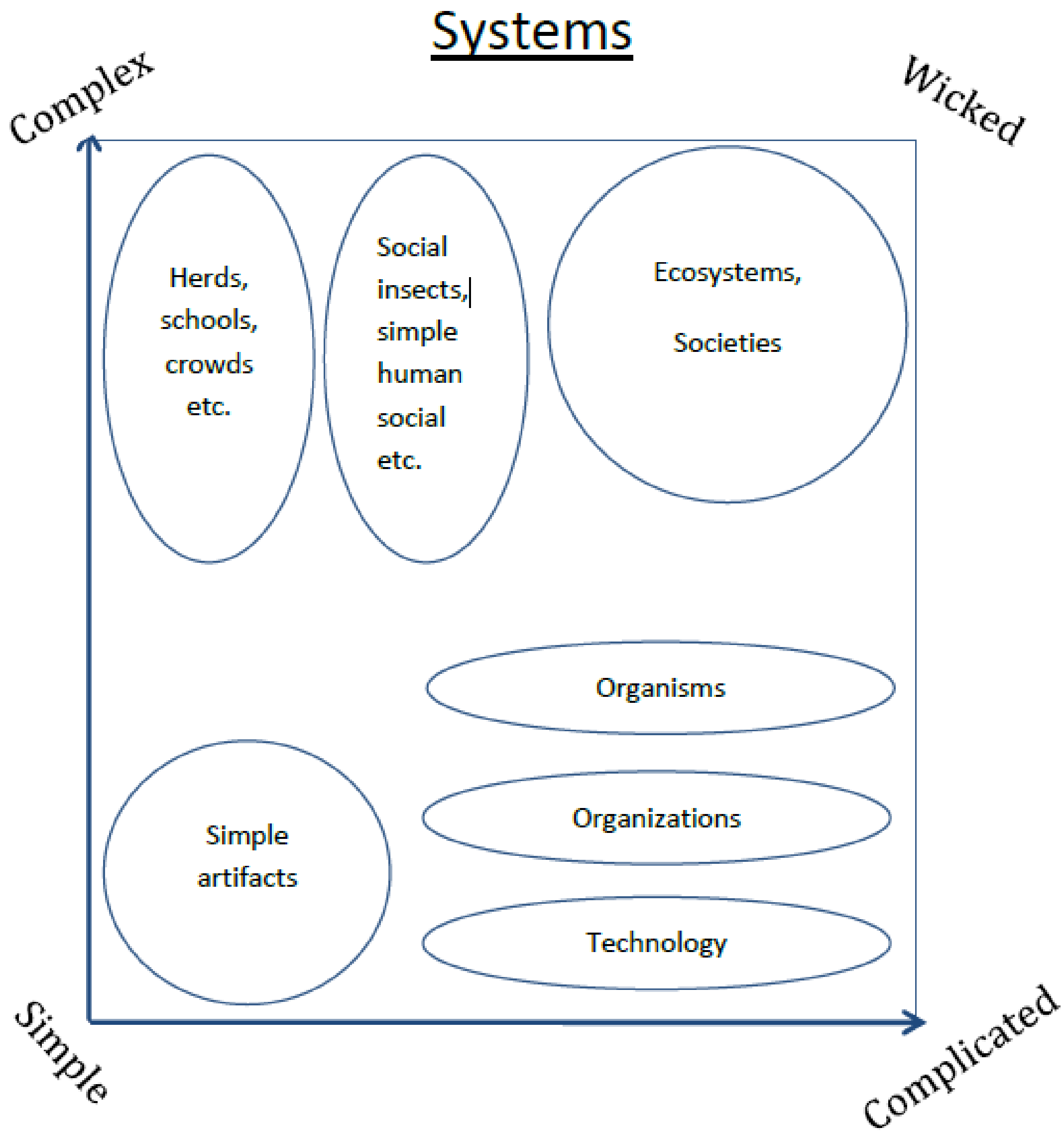


Figure 1 - We here map different types of systems onto the complexity-complicatedness plane to roughly indicate where many or most of the problems encountered in different types of systems fall. Near the "complex" and "complicated" corners we find paradigmatic examples, such as schools of fish and technological artifacts, respectively. In the "wicked" corner we find examples, such as ecosystems and societies, that are probably straightforward to accept as partaking in both complexity and complicatedness at the same time. As we move away from the corners, the placement of the examples in the diagram becomes more contentious and it is well to point out that the idea here is not to precisely classify the systems that we have used as examples. There is considerable room for argument about where they could be placed, how they should extend across the diagram and what exceptions that may exist. It can be viewed as a strength of the diagram that it can serve as a basis for such discussions. By "simple human social" we mean social sub-systems that are relatively unstratified in their organization and that, although part of a greater societal system, may be considered to some extent in isolation and in terms of agents and environments on a single level of organization; say for instance the social interactions between children in a schoolyard. These would be examples of social systems that can be straightforwardly studied using agent-based simulations.

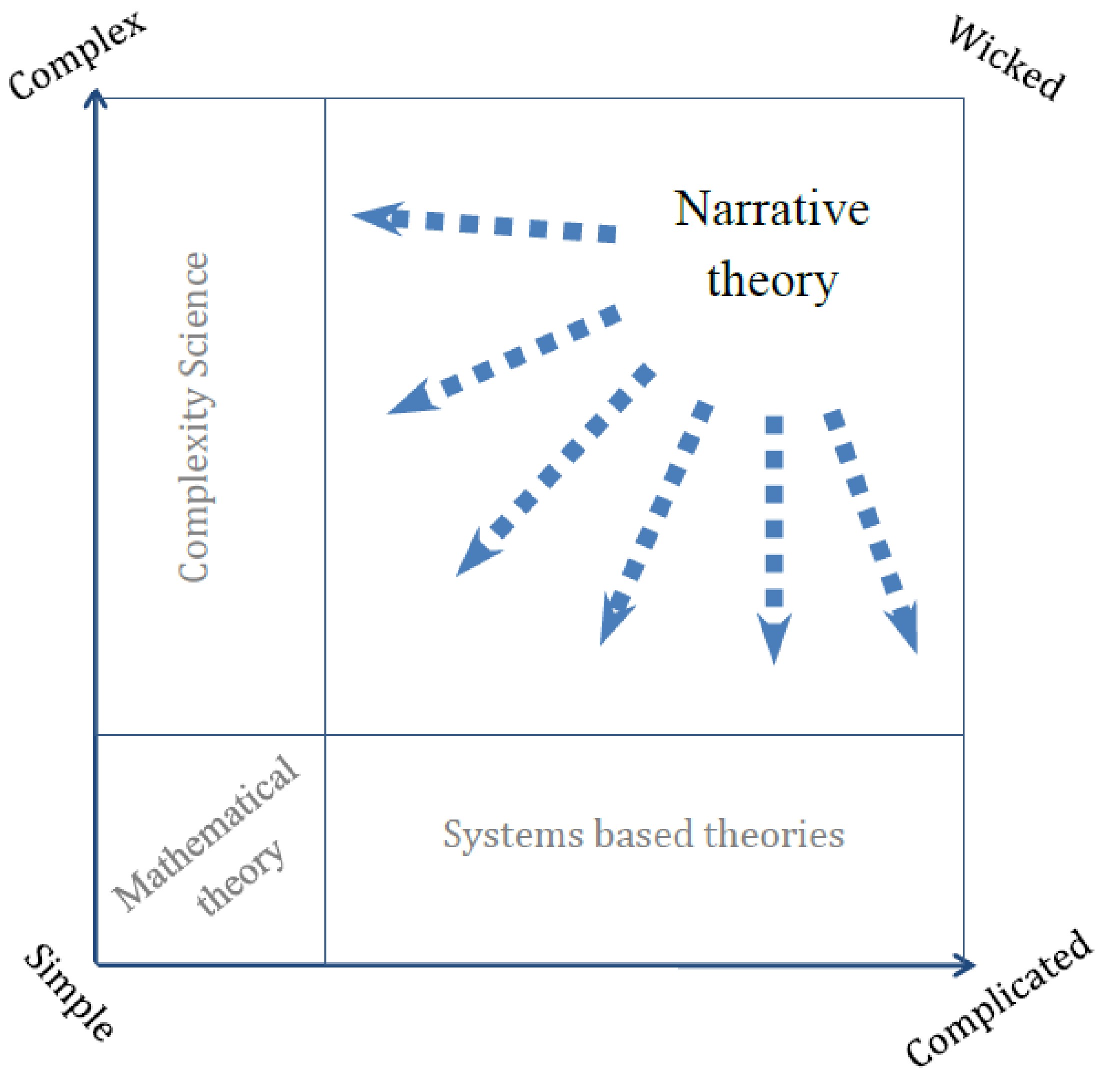


Figure 2 - On a plane described by a complexity- and a complicatedness axis, we here may schematically indicate what sort of problems that different approaches are strong at dealing with.

Why, then, would not a combination between formal complexity science and systemic approaches be the answer to this challenge? After all, we identify Wicked Systems as being both complex and complicated. One reason why the combination works poorly is that the formal methods that we thereby combine derive their power not from the presence, but from the absence of, complexity or complicatedness in systems. They rely on simplifications of either the structure or the dynamics of systems (or both), and for wicked systems we can frequently do neither while maintaining acceptable levels of realism. For example, engineering does not work because technological systems are complicated. It works because technology can be constructed such that it is not complex. For complexity science, even a cursory review of the literature clearly reveals that it excels specifically in dealing with systems toward the top-left corner of the diagrams in Figs 1-2; i.e. systems that are complex but not very complicated. Combined approaches thereby combine the weaknesses rather than the strengths of the constituent approaches.

5. A synthetic approach to innovation

These new "developmental" approaches to innovation address these methodological problems, and they do indeed pursue a methodology where historical case studies play a central role. Within the INSITE project, as a part of the research conducted under the related MD project, we have developed a provisional synthetic theory (see Andersson et al. 2014) and a transition model that combines and extends on some of the components that we find in this "new potential connection". This development has primarily taken place in the context of pre-historic cultural evolution, which we will return to below as a framing to understand the modern Innovation Society.

These components, and others, have been presented at a series of workshops that have been organized as part of INSITE[8]. Beyond this theoretical direction, these workshops have played an important role in the consolidation of a community of researchers interested in understanding innovation in complex adaptive systems.

The three main ingredients in this synthesis are Exaptive Bootstrapping, Generative Entrenchment and the Multi-Level Perspective. As an overarching logic, Niche Construction Theory also plays a central role. Exaptive Bootstrapping was introduced above, and we will now briefly introduce the other components to see how they each contribute crucial pieces of the puzzle.

[8] "Innovation, society and complexity: a dynamics of detecting, solving and creating problems" March 21 13, 2012; (2) - "Transition and Stasis in Society and Biology: models, theories and narratives" March 18-22, 2013; (3) - "New Data – Old Theories: The Future of Theorizing about Innovation in Complex Adaptive Systems" May 5-8, 2014. All these workshops were held at the European Centre for Living Technology in Venice, Italy.

6. Multi-Level Perspective

Also addressing the proneness of cultures to lock-in is the Multi-Level Perspective (see Geels 2002; Geels and Schot 2007; Geels 2010; Geels and Kemp 2012), which focuses on what conditions need to obtain for fundamental transitions to take place. Different areas of activity, in the context of palaeolithic cultural evolution – for example storage, food preparation, domestic fire handling, construction of dwelling structures, foraging, hunting, raw material procurement, and so on – would here be referred to as sociotechnical regimes organized into a sociotechnical system. Regimes evolve to become specialized and separated to reflect differences in function. But at the same time they will become entangled and coordinated: horizontally because they are all part of a larger project of maintaining the wellbeing of the society and vertically because they will rely on and share more entrenched and fundamental technology and practices.

Regimes will come to serve certain functions in relation to one another, and by fitting well into the sociotechnical system, important and well-connected regimes have an "internal fitness" that can trump even substantial "external fitness" of challenging regimes[9]. Regimes will also be resilient to radical changes in their function for the exact same reason. Most innovation will be incremental and channeled into the regimes, essentially making them better, faster and cheaper while preserving their function. Moreover, the hierarchical arrangement described by Generative Entrenchment will apply both within and between regimes: some parts of them will be more free to change while others will be more entrenched, and in the same way some regimes will be more dynamical and others more static.

The sociotechnical system, along with all other relevant aspects of the environment (other groups, ecology, climate etc.), collectively form what is referred to in the Multi-Level Perspective as a landscape. Changes and shifts in this landscape are generated both within and outside of the sociotechnical system, often gradually and over time. Since the landscape contains the regimes, it will pull these, as it were, and generate stress in their configurations. As stress builds, rifts may

[9] A modern example is the use of fossil fuels. Everything from engine designs to extraction (of resources), conversion (into fuel), distribution (of fuel), consumer expectations, infrastructure and workforce training is finely tuned and adapted to their use. So even if new technologies have a demonstrably better potential they will still face an uphill battle: the incumbent technology has constructed the entire niche in which the fight will play itself out.

form in the sociotechnical system as regimes come to fit in poorly, reducing their internal fitness, and offering windows of opportunity for fundamental change.

Whether or not a transition really will take place depends on the availability of challenging minor regimes[10]. Minor regimes fill important but more specialized roles and they serve an important role in the innovation dynamics because they sometimes turn out to be exaptable into more major roles. Modern examples include things like specialized types of propulsion, materials, energy production and so on in niche applications (e.g. military, space etc.) where ad hoc inventiveness is called for, or for that matter major regimes unique to certain countries, cultures and so on. The reason why regime-level radical innovation needs a long period of relative isolation as a minor regime is that whole new systems of practices do not appear overnight and a minor regime must have developed quite a bit before it can hope to take on even a crippled major regime.

7. Niche Construction Theory

Niche Construction Theory (NCT e.g. Odling-Smee et al. 2003; Laland et al. 2007) is a fairly young approach in evolutionary biology that challenges the strong delineation between, on the one hand, what adapts, and, on the other hand, what gets adapted to. It holds that, quite frequently, organisms alter their environment (by their behavior) to fit them while they undergo alternations to fit this environment. This is a quite radical departure from neo-Darwinian thinking, and one that is rife with methodological challenges. For example, population genetic models typically view evolution as a sorting of variants under natural selection and other biases that are kept constant during this process of sorting. Under the NCT view, the external environment that is implicit in the neo-Darwinian view, changes dynamically and selection pressures are neither constant or external to the evolutionary process. This also challenges the sub-division of biology into disciplines, most importantly the study of ecology and evolution as two separate subjects.

NCT is a highly general idea, and perhaps as a general idea it is not as new as it is in its worked-out biological incarnation. Very similar ideas have long been pursued in the social sciences. But

[10] Referred to as niches in MLP – a choice of terms that we think would be confusing in a context where terminology from ecology is also used.

on the other hand, this congruency also opens up paths for cross-disciplinary learning about such processes. NCT has been applied in the context of cultural evolution (e.g. Laland et al 2012; O'Brien and Laland 2012; Laland and Brown 2006), but the focus has been on the effect of culture as a constructed niche on biology. Although this is of great interest, NCT is also useful for understanding how culture itself is something that adapts and gets adapted to at the same time; the same delineation problem that applies between organism and environment applies also between culture and environment.

8. Generative Entrenchment, and a brief "animating" example

To "animate" the above concepts somewhat, and to introduce some additional concepts related to the theory of generative entrenchment (Wimsatt, 2012), a brief (and highly tentative) illustration is provided here.

Let us consider the organization of Acheulean communities at the Gesher Benot Yaaqov (GBY) site (~800Ka) as described by Goren-Inbar (2011). Two persistent Major Regimes can be particularly well established: (i) raw material procurement and (ii) lithic production. GBY hominins primarily used basalt, quarried from nearby locations, as raw material. Slabs were reduced into smaller pieces using methods of which at least two have left persistent traces: large rock percussors and levers. Many parts of the quarrying practices cannot be reconstructed, but it is clear that this must have been a collective activity. What emerges is a coherent sociotechnical Regime, consisting of multiple types of artifacts, individuals, knowledge and sites and whose continuity spans 50Ky (Sharon et al 2011). The quarrying Regime must have been entangled with numerous other Regimes, but we can safely infer that it must have been particularly strongly entangled with a tool production Regime. Both soft and hard percussors were used, and a high level of knowledge and control is evidenced by the fact that despite great variability in blank properties the resulting tools were remarkably uniform. Also here we see a system of knowledge, artifacts and agents, tangled up into a coherent Regime, filling a high-level role in an overall socio-technical system. These two basic Major Regimes we see as part of a sociotechnical Core: a system of mutually adapted and refined Major Regimes, of high, or even extreme, persistency: a "way of life" and the major pacesetter of activity in the community. Generative entrenchment is key to understanding the formation and workings of a sociotechnical Core and its more specialized derived Edifice. The Core is evolutionarily adapted to be highly generative in the sense that it permits the flexible design of derived Edifice Regimes that deal specifically with the current environment and its vagaries. Consequently, if you disturb the Core, you disturb the whole Edifice that it supports, and its capability of flexibly adapting to the environment. In GBY we see evidence of the base of such a hierarchy and hints of the Edifices that it supported. Although derived Regimes leave few persistent traces, low-level lithic tools were obviously used in many roles. Some direct uses, all of which represent sociotechnical Regimes, have however been documented, such as nut cracking (Goren-Inbar et al 2002) and butchering (Rabinovich et al 2008). There is also evidence of woodworking (Goren-Inbar et al 1992), strongly suggesting a general material processing use of basic lithic tools.

9. From the past into the present

As we discussed briefly earlier, the Innovation Society represents a momentous shift in how innovation processes are managed in human cultural systems: innovation becomes an end in itself, we begin to explicitly improve our capability of innovating, and we become dependent on innovation itself – not the functionality of the fruits of innovation. But it is by no means the first important transition in the history of human and hominin culture, and the story of how human culture arose, over the course of a few million years, from a rudimentary Great Ape culture in the Pliocene is both of great general interest and of great importance for understanding our current predicament. Innovation has been there all along, but the organization that surrounds it – its biological and cultural components alike, and together – has changed.

We will start from the beginning of the archaeological record, some 2,6 million years ago in Africa and follow hominin organic and sociotechnical evolution through the emergence of a rudimentary hunter-gatherer lifestyle and the spread of erectoids across the Old World. We hypothesize that a basic Human Sociotechnical Organization formed in this period. The path that we have chosen through the thicket of archaeological and palaeontological evidence (and their interpretations) is one that emphasizes the interplay between diet, physiology, ecology and the generativity of modified lithic technology.

The emergence of the Oldowan around 2,6mya (Semaw et al. 2003) and its spread across East and South Africa would be the first step towards establishing what we might call a Human Sociotechnical Organization. But it is likely that the organization of the overall Oldowan sociotechnical system would still essentially be that of the Great Apes, with a set of quite separate regime systems rather than a hierarchy of regimes. The reason why this can be suspected is that butchering is the only verified use of Oldowan tools before the end of that period. This suggests that the full generativity of lithics does not appear to have come into play yet at this point. While there exist indications of uses of lithics besides butchering in the early Oldowan (Beyries 1993), the evidence is tenuous (Domingues-Rodrigo et al. 2005). So it appears likely that if such uses existed, they would have constituted minor regimes - - paving the way for, but not yet constituting, a more complex organization that lay ahead.

We propose that the Human Sociotechnical Organization originated in the realization that lithics afforded manipulation of a wide range of materials besides animal carcasses. This general affordance provided exceptional leverage in terms of the range of implements that could be made (Davidson and McGrew 2005). This is an example of what we mean by a portal innovation: its generative effects on the sociotechnical system cannot have been part of the reason why it was initially adopted into a general role. Modified lithics would sneak in under and transform virtually all activity that relied on processed materials, and in the process it would also over time spawn new such activities that had previously been unthinkable; e.g. spears, hafted points, big game hunting, hide working etc. The scene was set for a major re-organization of the sociotechnical system: from something resembling the organization of Great Ape technology to a hierarchy with a strongly entrenched base and more and more flexible regimes upward.

Signs of such a shift appear towards the end of the Oldowan and the beginning of the Acheulean. The earliest direct sign is evidence found in late East African Oldowan tools (Keeley and Toth 1981; Beyries 1993) of the application of lithics to a wider variety of materials, and in Acheulean tools of similar age (Dominguez-Rodrigo et al. 2001). Another sign suggestive of innovation involving physiological, cultural and environmental factors are concurrent transformations involving physiology, cultural organization and ecological interactions. The shift between H. habilis and H. ergaster brings many physiological changes, such as an increase in body mass, encephalization, a reduction in masticatory musculature and post-canine tooth size, and an adaptation to a more modern mobility pattern with an essentially modern postcranial anatomy and thermoregulation (Plummer 2004, Wood and Strait 2004). It also brings evidence of behavioral changes including food sharing, change in land use patterns and in general the emergence of a rudimentary hunter-gatherer lifestyle (see e.g. Snodgrass et al 2009 for a review). The first hominids found outside of Africa (at Dmanisi, Georgia, ~ 1.75Ma; see Vekua et al. 2002; Lordkipanidze et al. 2013) are also dated approximately to this period, and H. erectus is subsequently found all over the Old World in a wide range of biotopes. The thesis that a new sociotechnical organization can have emerged that provided key abilities from early on is buttressed by (i) the fact that Dmanisi tools are Oldowan in character rather than Acheulean, (ii) by the primitive physiology of the Dmanisi hominids (they were not fully developed erectoids; see Vekua et al. 2002; Lordkipanidze et al. 2013) and (iii) by the low frequency of bifaces in East Asia and the generally low affinity to western Acheulean bifaces in those that have been found (Norton et al. 2006; Petraglia and Shipton 2008). This pattern would then be consistent with a migration initiated early during the External Innovation Cycle. The characteristic Acheulean bifaces would be an effect as much as a cause of this transistion.

The Early Human Sociotechnical Organization certainly witnessed substantial flexibility relative to ecology and climate, but notably no trend towards diversification in resource exploitation. To the contrary, the trend was towards narrowing and climbing higher in the trophic system and the Neanderthals finally occupied a niche at the very top, typically specializing heavily on one or a few species (see e.g. Stiner 2002; Kuhn and Stiner 2006; Gaudzinski 2006; Gaudzinski-Windheuser and Niven 2009). A logical development would be to follow the path of refining exploitation strategies for the best yielding resources that were already targeted and for which considerable sociotechnical adaptation had been achieved. That is, to move to larger game and towards being able to target them as efficiently as possible; i.e. fat-rich prime adults rather than only young and infirm animals. The Early Modern Sociotechnical Organization would be hierarchical and exhibit a system of linked regimes, but they would primarily be subservient to an ever-narrowing set of top-level regimes by which the groups would live and die. Few of these, perhaps (at least locally) only one, would be directed at obtaining food. The sociotechnical system developed to maximize output and minimize risk, but it did so path-dependently and constrained by its own organization. The sociotechnical organization of the Upper Paleolithic/Late Stone Age, from ~45ka, which we might call the Modern Human Sociotechnical Organization if we were to deal with it here, would be tempting to characterize as a break with the pattern of homing in more and more closely on bigger and bigger prey to that of being able to home in on several targets at the same time and to be able to swiftly change targets as needed.

This is clearly not possible to achieve by the incremental improvement of a big game hunting regime, and reliance on such a regime must have been exceptionally hard to break out of. Everything from technology to hunting practices, dwelling places, group structure and size, social interaction strategies (within and between groups) and conceptions of value and identity would be co-adapted to the occupation of this niche and contribute to a powerful lock-in.

The Upper Paleolithic is characterized by an entirely new level of flexibility when it comes to the species of animals and plants that are targeted, and when it comes to ways of surviving in different environments. It also brings features of human culture that we think of as central to what it means to be human, such as symbolism and art; features that are not entirely missing in the earlier record but that become universal (or at least very nearly so) during the Upper Paleolithic. But the robust presence of such elements in the record before the Upper Paleolithic has an important impact on the explanations that can be put forth. If H. sapiens was capable of the features that we connect with the Upper Paleolithic – and so-called behavioral modernity – earlier then the hypothesis that some key capability appeared to trigger the Upper Paleolithic and a more modern lifestyle is undermined. The hypothesis is further undermined by the fact that transition to the Upper Paleolithic does not coincide with any discernable change in human physiology. Remains that meet the criteria for H. sapiens appear already some 200ky into the past, and even if physiological changes were ongoing before and after that time, nothing in particular happens on that front around the approximate time period of 100-50ka where we might expect a physiological (e.g. cognitive) trigger of the Upper Paleolithic.

Even a cursory examination of reviews and reports shows that concept of behavioral modernity is under siege. For instance, McBrearty and Brooks (2000) and McBrearty (2007) consider a wide range of MSA[11] reports of artifact types often taken to be diagnostic of the UP, and in a recent review Shea (2011) finds that the idea of Mode 4 technology being unique to some behaviorally modern UP/LSA variant of H. sapiens has no archaeological support; McCall (2006) and Soriano et al. (2007) review the MSA Howiesons-Poort evidence, concluding that it was a separate and recursive tradition not ancestral to UP technology; Hovers and Kuhn (2006) collect studies of intermittent “modernity" in the LP and MP; Hovers and Belfer-Cohen (2013) provide a review of

[11] LP = Lower Palaeolithic. MSA = Middle Stone Age. MP = Middle Palaeolithic. LSA = Late Stone Age. UP = Upper Paleolithic. LGM = Last Glacial Maximum.

the Levantine MP to similar effect. The emerging view is that transitions were more gradual than revolutionary.

For the forager-producer transition – i.e. the transition from the Paleolithic to the Neolithic – the physiological explanation obviously falls by the side as an explanation. Overall the discourse shifts weight from biology to sociology and anthropology (with post-LGM climate change as a backdrop.) But despite a theoretical shift of emphasis, the prescriptions of older universal models here are not too different from those that we have discussed so far, and neither are the old and the emerging empirical patterns. Also here we see the new wealth of detailed data being interpreted as a shift from a revolutionary to a more gradualistic pattern (e.g. Maher et al 2012) and we see a search for new theoretical traction (e.g. Hauser 2012).

The Neolithic saw a new wave of innovation, and one with a great deal more cumulativity than what was the case before among mobile bands of hunter/gatherers. Over the course of as little as a few hundred years, year-around settled hamlets emerged, and over the millennia that followed, cities, urban systems and civilizations with entirely new ways of organizing societies and innovation; for example, with craft specialization, organized warfare, a stratified society with castes, and with long-distance trade. The transition to farming is in many ways similar to the earlier transitions in the sense that it is now known to have had precursors far back in time before a new integrated sociotechnical system based on farming came together. But here, just like with the Middle Paleolithic in relation to the Upper Paleolithic, it still does not seem to be a case of simple gradualism. The new emerging empirical picture here places considerable strain on models that have been the basis of much research during the last half of the 20th century; see e.g. Barker (2006).

It is striking that it is so hard to identify the transition that really made the difference here: the transition that really made us human. The transition in which lithic tools emerged ~2.6Ma appears not to have brought us qualitatively too far from what we today observe among Great Apes, but the next transition and the first exodus from Africa ~1.8Ma seems to have been much more remarkable since it seems to have made culture much more cohesive and hierarchical. We did not discuss the transition to the Middle Paleolithic some 400-300Ka – which meant yet another leap with universalization of domestic fire, hafting and a domestic organization into camps (e.g. Rolland 2004; Roebroeks and Villa 2011). This transition seems to have deepened the entrenchment of big game hunting. The transition to the Upper Paleolithic brings a cultural capability that builds upon this hierarchical organization, but that revolutionizes it. Rather than (like any animal) facing a strong tradeoff between specialization and efficiency, humans came to be able to combine and alternate between several deep specialization; e.g. being able to fish and hunt large and small game at the same time using advanced technology and strategies. This likely made culture much more open-ended, and it also appears that it is this capability that slowly builds up the potential for a leap to actually controlling the environment in a much more strategic way, which was the case in the Neolithic.

Change brings change here, but it does not always bring change. For long periods of time, sociotechnical Cores appear to stabilize culture and prevent radical innovation from taking place. Taking these theoretical lessons further we have developed a Provisional Transition Model, to be introduced next.

10. The Provisional Transition Model

The Provisional Transition Model is a more specialized articulation of what we have outlined so far, and it combines and extends on their concepts and models. As a developmental evolutionary model it is essentially historical. One might say that it aims to describe an abstract history of a transition, to be instantiated by specific empirical content in application to case studies. In this sense it is inspired by the methodology of sociological transition studies (e.g. Multi-Level Perspective; see above) and of how major paleobiological transitions are beginning to be conceptualized from a developmental perspective (e.g. Erwin and Valentine 2013).

The model is derived from the components introduced above, and by Andersson et al. (2014a). The aim has been to align, and align to, this intellectual substrate to create, so to speak, the preconditions for traction between theory and empirics.

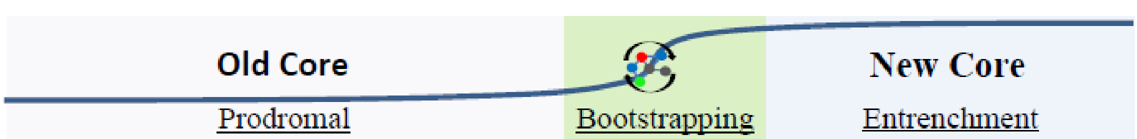
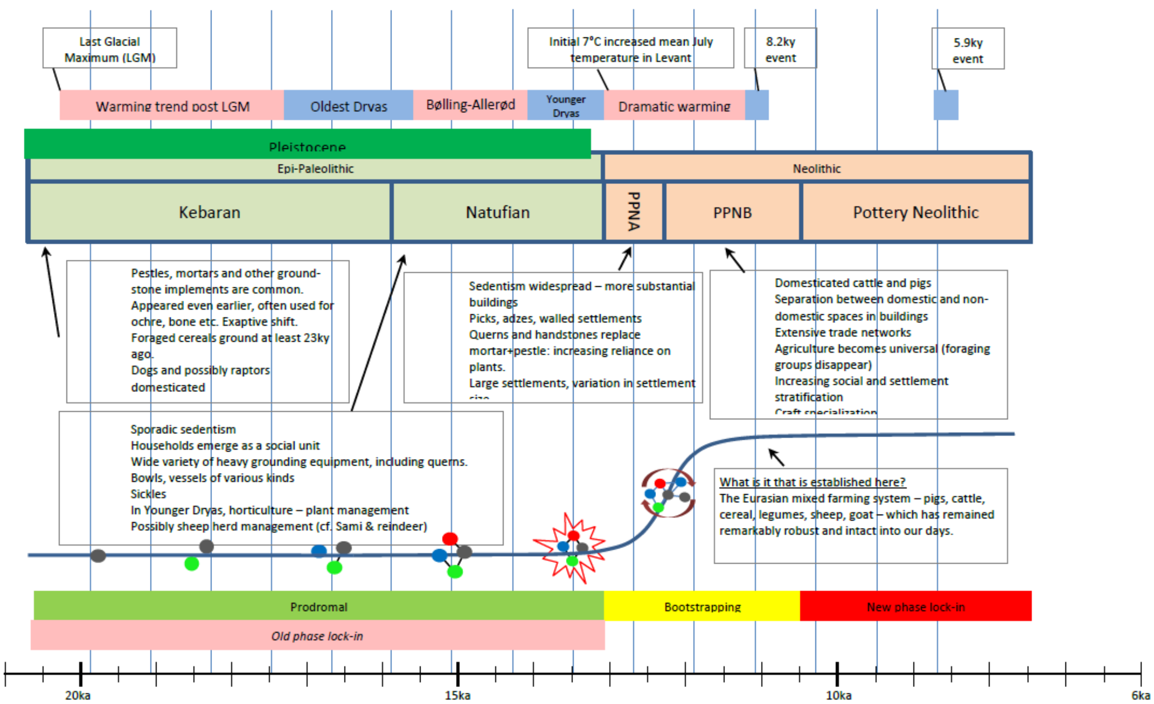


Figure 3 - Provisional division of a transition into phases with a focus on transition. Our initial focus on transition does not signify a disregard for dynamics during periods with undirectional change; to the contrary.

We have identified a strategic scientific crux to be addressed as follows in the context of paleoanthropology; we will thereafter move to interpretations of the emergence of the Innovation Society. The emerging view in archaeology and paleoanthropology sees transitions as more gradual than revolutionary. I hold that neither "gradual" nor "revolutionary" describes the pattern particularly well and, moreover, that this age-old dichotomy itself is based on the linear, atomistic and simplistic neo-Darwinian model of how evolution works. The model to be introduced provisionally connects the mechanisms that this new empirical picture provides access to, with the evolutionary patterns that we are beginning to see – providing a glimpse of what a transition



could look like through new theoretical spectacles; see also Fig. 4.

Figure 4 - Superimposing the stages of the Provisional Transition Model over a summary of changes in culture and climate across the forager-producer transition.

We see transition as a replacement of an Old Core by a New Core (see Fig 3). The Core has substantial inertia since it provides a coherent overall strategy for subsistence; i.e. for constructing an Edifice of Regimes for dealing with a changing environment. It thereby enables its carriers to flexibly adapt within a certain range of lifestyles in a certain range of environments and conditions. But the Core is constantly subject to stresses of different kinds: from biological evolution, from within culture, and from the environment (e.g. climate change, migration, ecology etc.). Internal stress we see as cascades of cultural re-adjustment to a constant process of invention by which societies deal with everything from daily life to major environmental change. Most novelty will be unremarkable and aligned to the Core – it will be part of the flexibility that the Core is adapted to provide. But certain types of novelty may also come to subvert the system that it originally fit so nicely into. One such dynamics is when new elements represent some sort of special solution to a peripheral (but often important) problem or opportunity; e.g. plant processing techniques in the Epi-Paleolithic, space technology today or why not toys? This is what we refer to as Minor Regimes. These become refined in their specialized roles and may stably remain there for prolonged periods of time. Over time they may however also expand, enter into new uses, and multiply. Especially Minor Regimes that cater to external stress with increasing importance (e.g. plant processing under climate amelioration post Last Glacial Maximum) we think will generate substantial friction with the old Core. The pre-transitional way of life remains in charge during this Prodromal Phase and Minor Regimes still dance to the tune of the Old Core; they keep accumulating, but remain on the margins of the dominant Core. On the surface, this pattern may look simply "gradual", but this belies a dynamics that is much richer than what can be described as mere accumulation. We refer to the mix of Minor Regimes that emerges during this Phase as a Substrate. At some point, the cultural system reaches a breaking point: a Window of Opportunity. This is the beginning of the transitional Bootstrapping Phase, bringing a qualitatively new change dynamics. A New Core now begins to coalesce from a Substrate of increasingly connected and refined Minor Regimes. The Substrate at this point both pressures the Old Core and offers an alternative to it. The nascent New Core, however, is not time tested and finely tuned: innovation will be radical, and change tends to generate violent cascades of new change. The Bootstrapping Phase gives way to the Entrenchment Phase as the New Core undergoes Generative Entrenchment and re-establishes a new way of life. Innovation again becomes subordinated to a hardened set of basic cultural strategies.

11. The Innovation Society revisited

The Innovation Society does not really break with old traditions as much as one would think when it comes to the fundamental dynamics of innovation. Basically the same mechanisms are at play. But it does do something highly powerful and peculiar from a natural historical point of view. It installs the innovation engine itself into the Core of society! We see the emergence of innovation as a Regime in its own right. Innovation is no longer simply a process that just happens as we go along – something that emerges from exercising our cultural strategies – but a goal that we consciously pursue which we ideologically look upon as virtuous, and which we have come to be dependent upon. This is precisely what Generative Entrenchment entails: innovation is now necessary for the functioning and stability of the whole sociotechnical system. But at the same time, in other ways, our blind pursuit of change and novelty means that society is exposed to the danger of being undermined by the mass of unforeseen effects that we cannot avoid due to Ontological Uncertainty.

We clearly need to recognize that something fundamental has changed over the past century. Innovation is our tool for dealing with crises – so we clearly need to innovate our way out of what we called the meta-crisis that currently besets our (by now) wholly global cultural system. But at the same time, innovation has also caused the metacrisis; i.e. innovation as a Regime – innovation as conceived by the Innovation Society Ideology.

As we mentioned above there appears to be no off-the-shelf approaches for organizing innovation in ways that lead to a sustainable path into the future. In fact, taking the deep historical perspective that we did here, the magnitude of the goal of sustainability comes more clearly into view. Let us illustrate this by a comparison between human cultural and biological innovation.

Life on earth has surely seen its ups and downs during its multi-billion years tenure. However, most grand upheavals during the past 543 million years during which complex ecosystems have been established do appear to have been triggered by external events, such as meteorite strikes and volcanism. Something apparently keeps biological innovation from going to states where one species simply leave all other species behind – gobbling up all resources and generally destroying the preconditions for its, and potentially all other species', survival. One factor here comes across as particularly important: organisms have only one body – at least at a time. The consequence of this is that if they specialize and become more efficient at one thing, they automatically become worse at other things. There is a tradeoff between generalism and specialism.

What appears to have happened with the Upper Paleolithic ~45Ka is that our species did something that no other species has ever done before. Prior to this we had – which is remarkable enough in itself – gone from a savannah living broad-spectrum generalist (basically a savannah-living member of the Great Apes) to a strongly specialized top predator over the course of 2 million years – capable of outcompeting large feline and canine predators wherever we turned up and in basically whichever habitat we found ourselves. We did this not by developing the physiological features of large predators, but by cultural adaptations – by innovation – and by physiological adaptation to innovation.

What happens in a top-predator niche normally is that a species gets stuck there. If you are strongly adapted – like for example a lion – to hunting and killing prey weighing 100's of kilograms, armed with dangerous defensive weapons and strategies, you cannot at the same time begin, for example, to compete effectively with foxes at hunting rabbits. Now it so happened that the capabilities that we had gained in the process of becoming top predators in our own way contained the affordances needed to also to break out of the top-predator niche. These affordances went unnoticed for a long time – the attributed functionality of our cultural system, and our physiological capabilities to maintain such a system, were very similar to those of the lion. The profound differences between how lions and humans were top predators, however, meant that their future evolutionary paths were tremendously different. The lions remained where they were ecologically, while humans, at some point, managed to maintain cultural systems that specialized at several things at the same time.

If one has to choose one factor where humans really break with nature, this has to be it. We rid ourselves from what is probably the single most stabilizing factor in ecology. We are now reaping the rewards of this capability, and with the Innovation Society we have not only taken it to the extreme: we have short-circuited it by making innovation necessary in itself. Can we stop this freight train? Can we become sustainable without stopping it? Can we rewire it so that it automatically strives to a sustainable state?

INSITE has identified a number of critical flaws in how the Innovation Society deals with innovation with regard to its tendency of accumulating negative by-effects, many of which (to add to the trouble) may not even exist at the time when the novelty first appears. The most important of these is probably that there is a lack of incentives to identify and deal with such negative effects. Therefore there is also a lack of organization to detect and deal with these effects. Everybody wants to own the positive effects (in particular the positive economic effects) but who wants to own the negative effects? Who wants to even detect them? Who would go first?

Is it only a matter of daring to break with the specter of a global collapse if we rebel on the prescription of the Innovation Society Ideology? Probably not. The Generative Entrenchment of the core mechanisms of the Innovation Society mean that everything actually does depend on it: the threat is probably by all means real. It has made itself real – and by Generative Entrenchment – the more real it is, the more real it gets. This leaves INSITE – perhaps – with few real answers, but with a great deal of new questions.

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