21

Conclusion

What Is the Message Thus Far?

The main message of this book is that we need to bring together a Complex Systems approach, a focus on Information Theory and the dynamics of information processing, and the long-term study of invention and innovation as seen from an emergent, ex-ante, perspective to study system trajectories from the past to the present, instead of explaining the present by invoking the past. This perspective avoids the trap of much current science, which presents linear arguments about cause and effect in a limited number of dimensions. The dynamic socioenvironmental system of which we humans are a part is in the true sense of the phrase a complex system and should be studied within a theoretical framework that is appropriate for such phenomena. Hence, I have tried throughout this book to emphasize that approach, which enables us to develop a much more intricate, holistic perspective that intellectually fuses information obtained in a wide range of disciplines.

Another important and encompassing message of the book is the fact that our sustainability conundrum is a societal one and not an environmental one. Our societies have created the current degradation of the environment, from CO_2 emissions to waste dispersal around the world. They have defined what they considered their environments, what they thought they could extract from them and dump in them, and later what they saw as their environmental problems. They currently try and find solutions for these challenges by mitigating the impacts they have on that environment, but often (though certainly not always) without a more fundamental analysis of the dynamics involved, so that many solutions remain relatively superficial.

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Moreover, the disciplinary and reductionist nature of much of our current science means that we look at the challenges and potential solutions in a disciplinary manner without being able to transcend the different disciplinary approaches and develop a holistic perspective. In particular, sustainability has for a considerable time been predominantly investigated and researched by the natural and life sciences without any contribution from the social sciences. In more recent years, the latter have now been solicited to make a contribution, but in many instances the questions they were asked to respond to were ultimately defined in terms of those natural and life sciences, rather than encouraging the social sciences to develop their own perspective. That is beginning to change, and this book hopes to contribute to that change, in particular by defining sustainability as a societal challenge rather than an environmental one, and thus subject to the societal, political, economic and commercial dynamics occurring globally.

Indeed, once one adopts such a societal perspective on the great acceleration of resource depletion, pollution and destruction of, for example, the world's biodiversity, another great acceleration hits our radar screens – that of the rapid increase in technological innovation that is currently manifesting itself, after two and a half centuries, in the material and energetic domains – notably in the domain of information processing. It is my contention that this acceleration – called the information and communications technology (ICT) revolution throughout this book – will so rapidly and drastically change our current societies and their institutions that it needs to be seen and investigated alongside the environmental challenges we are facing, because the latter will have to be dealt with by future societies very different from our current ones.

In order to put this ICT acceleration in a proper perspective I have argued for combining a number of different, or at least infrequently used, perspectives on the topic. These include a different role for science in the current social and political context, in which science risks losing some of the trust it gained in the middle of the last century. Another part of this novel scientific perspective is using a Complex Adaptive Systems approach that looks at the history of our societies and environments from an a priori perspective, searching for the emergence of change as it occurred and occurs through time, rather than an a posteriori perspective that looks at the origins of the present against the arrow of time.

I have further argued that one must apply a long-term perspective to the evolution of our socioenvironmental systems for three reasons. The first of these is because some of the dynamics, both natural and societal,

are very slow and only perceptible over millennia. Secondly, a short-term view of such long-term socioenvironmental processes is like looking at a very ill patient (our Earth system) without any inkling of what the patient looked like when it was healthy. Thirdly and importantly, because without adopting the long-term perspective one is not able to observe the "change of change," the second order change that transforms the first-order dynamics over time. One therefore misses a major set of transformative drivers that play an important role, one that is only observable over many centuries.

Developing a long-term, global, and transdisciplinary complex systems perspective led me to search for ultimate rather than proximate causes for the emergence and decline of a wide range of societal phenomena – formulating a theoretical model that could indeed help me understand the dynamics of change in very different socioenvironmental systems, from past and present small-scale, local hunter-gatherer, and tribal societies to the incredibly complex globe-spanning societies of the present day. I found such an ultimate explanation when I realized that every society on Earth has always been an information society, because information is the only one of the three basic commodities known to humanity that can actually be shared among the members of a society. Neither energy nor matter can be shared because they are subject to the conservation principle.

Hence, I view human societal evolution as a feedback loop of the following kind:

> Problem-solving structures knowledge —> more knowledge increases the information-processing capacity —> that in turn allows the cognition of new problems —> creates new knowledge —> knowledge creation involves more and more people in processing information —> increases the size of the group involved and its degree of aggregation –> creates more problems —> increases need for problem-solving —> problem-solving structures more knowledge . . . etc.

For a major part of human evolution this dynamic was physically constrained by the capacity of the human brain's short-term working memory (STWM) to deal with more than a few sources of information simultaneously. However, around 50,000 BP, roughly speaking, the human brain had evolved to a point where its STWM could deal with 7 ± 2 sources of information, and that set in motion a relatively quick expansion of the complexity of the challenges that humans could deal

with, which I have here described as the (relatively rapid, and accelerating) development of tools for thought and action. These tools enabled human societies to organize their thoughts, their social organization, and their environment in ever more complex ways.

Taking this approach a step further, to the development of the relationship of human societies with their environments, I have then adapted Prigogine's concept of dissipative flow structures (1977), defining them as dynamic structures in which a flow of information-processing (organizational) capability outward from a group or society is complemented by an inward flow of matter and energy that enables the society's individuals to physically thrive. In the process, the feedback cycle driving such dissipative flow structures transforms the uncognized environment (chaos) into cognized knowledge (information-processing capacity).

I illustrated this by outlining how one may understand human socioenvironmental evolution on two different timescales, first the long-term of human cognitive and social coevolution over millions, and later tens of thousands, thousands, and hundreds of years, and then in more detail focusing on the succession of social, technical, and economic changes occurring over a couple of millennia in a particular region.

I then shifted back to theory and used simple models to clarify how I saw socioenvironmental evolution as driven by changes in information-processing structure within societies, leading to major institutional transformations. To begin with, I drew heavily on ideas developed by organization scientists about different forms of information-processing control structures: processing under universal control (in anthropology termed egalitarian), processing under partial control (also called hierarchical), and processing without central control (here called market-based). From a long-term perspective, the transitions between these kinds of information-processing systems are of particular interest, and I therefore looked at some of their affordances and limitations, which may have engendered transitions between these general kinds of structures. Initially, I did so from a percolation perspective, looking at communication in growing networks of interacting people. The networks involved are determined by two parameters, connectivity and interactivity (activation). Different proportions of both these parameters give rise to several states of the system, from highly localized and temporary interactions to localized permanent interactions, to a wider, but highly variable, activation of the network beyond the initial localized areas, and finally to the very sudden emergence of a network in which interactions can affect each other over very large areas.

Next, I have argued that this might be a way to look at the transitions between mobile small-scale societies, spatially fixed small-scale societies, a highly variable range of larger societies, and finally very large-scale (clustered) societies. Of course, this model is very abstract, but it merits attention in so far as it leads to further, more detailed, study of information-processing system state transitions that have occurred throughout human history. Within these variously sized societies, one can then observe some of the characteristics of the organization of information processing – and in particular the role of information processing under universal, partial, or no control. Looking at the characteristics of such systems independent of the nature of the nodes or the connections between them, we can outline how combining hierarchical and market-based systems (i.e., systems without overall control, in which actors only have partial knowledge) may have interacted to generate clusters of nodes that one could interpret as networks of towns. One can thus make a coherent argument for considering the major societal transformations that we know from archaeology, history, and anthropology as due to an increase in knowledge and understanding, and thus an increase in the information-processing needs and capabilities of human societies.

It follows from this basic model of information processing that invention and innovation are at the core of what has driven our societies' coevolution between cognition, technology, institutions, economy, and environmental impact. I therefore next elaborated my perspective on invention and innovation, and in particular emphasized that our reductionist science has never really been able to deal with the process of emergence of new phenomena that is the main characteristic of invention and innovation. I have developed the argument that invention is a process of interaction between the realm of ideas (tools for thought and action) and the realm of the physical world and its phenomena. The centrality of my emphasis on information processing leads me to invert the traditional, positivist conception of the relationship between phenomena and ideas: objects are polyinterpretable and ideas give our perceptions of those phenomena temporal continuity and path dependency. The fundamental conceptual structure of tools for thought and action, and thus of ways of doing things, outlives objects and technologies even if in detail they are modified. Ideas determine how we look at things, what we see, and what we do not see. In the field of tension between ideas and phenomena, inventions occur owing to the interaction between both spheres that is fundamental to our basic assumption about the interaction between acquired knowledge and the observations in the real world that resonate

with them, between the reality of the world out there and our perception of it, much in the way in which Laubichler and Renn, in their "extended evolution" (2015), outline the interaction between evolutionary control mechanisms and the niches with which they articulate. This is illustrated with an example from (traditional) ceramic manufacture.

One of the implications of this approach for our overall understanding of cultural dynamics is that we also need to change our perspective on change and its absence. Rather than assume stability and explain change, as we regularly do in our current scientific practice, we have to view both change and stability (innovation and its absence) as two states of the same regulatory system, and to understand technical or cultural traditions as circumscribed by the things people have never thought about, rather than defined by the tools for thought and action they have conceived.

To cap the theoretical chapters that I have summarized above, I have elaborated a dynamical model of the different transitions that may have led from a simple, egalitarian, rural, and isolated village society to a (proto-)urban network, with an emphasis on how the temporalities of environmental dynamics have slowly but surely been invaded and overtaken by the faster dynamics of the societies interacting with them. The transitions involved have at different times driven the members of those societies to make clear de facto choices about whether or not to participate in the novel dynamics driven by the spreading of activation nets. This was an occasion to emphasize the importance of the second order dynamics that can be understood if one considers a sufficiently long period of societal change, but that are often not taken into account because our models are confined to a century or two. But it also serves to demonstrate that one can in effect model these kinds of transitions as bifurcations occurring in mathematical models that are themselves content-neutral.

The remainder of the book is devoted to the coevolution of western societies from the Roman Empire to the present, and to the challenges that the present state of that coevolution poses for the continued existence of our current global mode of life, mainly from an information-processing point of view. This begins with a quick and very sketchy summary of the long-term coevolution of European society and its global environment, essentially viewed from the dissipative flow structure perspective, emphasizing that this history was not a continual progressive evolution of society, but a process in which phases of relatively uninterrupted, apparently stable dynamics alternated with clear tipping points at which novel resources, institutions, ideas, and societal dynamics emerged. At each of these tipping points we can identify the end of an era in which the existing

mode of living outlived its optimal usefulness in dealing with an environment that had been changed to an important extent by the unintended and unanticipated consequences of its exploitation by a growing population. Whether the tipping point was triggered by environmental or societal dynamics, society had to shift from exploiting existing resources and adopted ways of thinking and doing to exploring novel approaches to interact with its environment and organize itself.

Although in the sustainability and global environmental change communities we have for some time now acknowledged that we are either close to, or at, a major environmental tipping point that threatens the continuity of our current way of life on Earth, we have not very often looked at some of the concomitant societal trends that may be driving our societies to their own tipping points, in the domains of demography, health, food and water, economy, finance, and others. I have tried to present some of these dimensions of our current predicament in an equally summary but poignant manner and attributed all of these so-called crises to one and the same second-order dynamic, the fact that our societal information processing apparatus has been overwhelmed by the unintended consequences of earlier (systemic or societal, unconscious or conscious) decisions.

Looking more closely at our incapacity to process the information necessary to deal with what is going on around us, I developed an argument about the drivers behind the acceleration we are currently living through. It seems to me that the discovery and harnessing of fossil energy during the Industrial Revolution removed the main constraint that had thus far limited the introduction of new inventions in society: the high cost in energy of implementing them. As more (fossil) energy became available, innovation in western societies accelerated. In the process, it affected the fundamental cognitive feedback loop that I have posited as responsible for the coevolution of society, technology, economy, and the exploitation of environmental resources. Early in that process, in the mid-nineteenth century, this acceleration also inverted the balance between our societies and their economies, from one in which the economy (in the form of exchange and trade) served society to one in which society became subservient to the economy, leading to the current free-market, capitalist approach.

Thus far, the speed of information processing in society had been limited by the need for society to adapt to novelty, and as that involved very large numbers of people, and network activation was for most of the nineteenth century limited to face-to-face and written communication,

such adaptation was still relatively slow. That changed with the introduction of electrical means of communication (telegraph, telephone, etc.), setting in motion a wide range of inventions that ultimately also included the electronic processing of information, thereby enabling another quantum jump in the speed and efficiency of our societies' information processing capacity and reducing its cost, paving the way for the developments that we now call the ICT revolution, and hugely accelerating invention and innovation in our societies as well as generating an overwhelming quantity of information. Not only did this development change the relationship we have as humans with space and time, but it also accelerated change in a number of societal processes that had been fundamental stabilizers to the existing societal order.

One of the important dynamics set in motion was the total loss of control over information processing, which in the heterarchical mode of communication that prevailed until the middle of the twentieth century, had ensured a degree of alignment of the members of any society around a set of values and ways to think and act. Now, anyone in the world can communicate with everyone. As a result, there is an exponential increase in different perspectives and values that are being transmitted. Hence, the boundary between signal and noise is to an extent disappearing, both nationally and globally. This in turn leads to increasing confusion and undermines the national and international orders among developed nations that, until now, have been based on (1) shared sets of values within each nation, (2) non-interference in internal matters between different nation-states, and (3) balance of power between nations or blocks of nations. We observe this currently in the emergence of alternative truths and international cyber-warfare.

An important aspect of this is the reduction of the dimensionality of our societies' "value spaces" (the totality of the shared dimensions along which a society measures value), under the impact of globalization, to a single dominant dimension – the lowest common denominator shared by different cultures and societies: wealth. This global trend is rapidly accelerating wealth differentials both within and between societies, while at the same time so reducing the diversity of ways in which members of a society can affirm their identity that it is leading to the intra-societal conflicts we witness today with the rise of populist, extremist movements in many countries.

An interesting model of the situation in which we find ourselves as a result of all this is the lemniscate that summarizes the approach of the resilience community (see Chapter 5). After a phase in which both the

energy and information flows increased continuously, and thus kept our societies more or less on track, we seem to be approaching a point where these flows no longer grow in tandem, and their growth no longer involves the whole of the members of society, creates fracture lines, and may ultimately be driving societies to the point where the highest levels of global organization may fragment into smaller entities.

To illustrate this fragmentation, I have briefly (and again summarily) described some of the processes that we can observe. First of all, there was the disintegration of the European political order that since the mid-seventeenth century was based on balance of power between nation-states and non-interference in the internal affairs of others. Next, political parties' most important role – connecting people in power to their power base in the population – is usurped by social networks, with important consequences for the functioning of our democratic systems. Third is what I have called "the spectacularization of experience." This process is slowly but surely detaching many people from the experience of reality, initially through increasingly intensive viewing of the media, and more recently by their spending large amounts of time on computer games.

The impact of the "big data" revolution is a fourth case in point. On the one hand, it has led to a huge concentration of power in the hands of a very small number of institutions, most of which are in private hands and can do with the information they gather more or less whatever they wish. But on the other hand, the collection of much more detailed data moves us away from the statistical approach to many domains such as insurance, medicine, agriculture, and others, where economies of scale prevail over detailed, adapted, small-scale information treatment. The issue here is that there is no government control over the use of these data to ensure that they are used to the benefit of all.

And finally, I have devoted some attention to the rapid emergence of automation, artificial intelligence and especially machine learning, which are clearly going to wreak havoc at some time in the future with our labor-based societies, creating important unemployment and annihilating the negotiating power of labor in the relations of production – if we do not in time find solutions to greatly elevate the level of general education in ways that promote human–machine collaborative problem-solving.

The fundamental and accelerating shift in information-processing structures that potentially risks overtaking societies' speed of adaptation makes it likely that we are approaching a fundamental transformation of societal organizations. It seems on a collision course with the existing value space of our western societies and those cultures and nations

elsewhere that are following the globalization trajectory. That value space, firmly anchored in the structure of a world that goes back to the Enlightenment, has not really evolved to the point that it can deal with the increase in information processing capacity that we have been seeing since 2000. This trend shall ultimately – and probably quicker that we expect – reach the developing world, where the technology is quickly having a growing impact. But in many parts of it, for example in sub-Saharan Africa, rural Latin America, and Asia, the local modes of human information processing are (fortunately?) still a barrier.

A major issue in thinking about the future is whether we should, or even could, slow down (or stop?) the current acceleration of technological and societal innovation. This would in my opinion either require an external constraint, such as a reduction in the availability of energy or an important increase in its cost, or an internal constraint, such as a move away from the idea that progress underpins all societal developments. Although the former may indeed occur at some unknown time, we cannot currently depend on it to change the course of our trajectory. This leaves us with the option to change both our western conception of the role of human beings and our idea that technological progress is unstoppable. But as this approach is very deeply anchored in our culture, changing it in a relatively short time would seem to be very difficult. Hence, I propose redirecting development in a more practical sense. This is not an original suggestion, far from it. I am here asserting my position in this field, and emphasizing the importance of the work already being done in this direction!

The process begins, in my opinion, with individuals in the developed world reengaging in the everyday dynamics of their societies, instead of leaving the management of these societies to delegates to whom they have essentially relinquished a very large proportion of their societies' decision power. As part of that process, we need individually and collectively to conceive of plausible and desirable futures for our societies, and because of the current speed of societal change, in choosing between such futures we need to shift our attention from assuming stability and explaining change to the inverse: assuming and designing for change and studying how to achieve (temporary) stability.

The next level up concerns the rebuilding of local and regional communities that have been deconstructed and individualized by globalization and the concomitant reduction of the dimensionality of our societies' value spaces. As part of that reconstruction, we need to correct the wealth discrepancies that are currently tearing many societies apart. In the

case of cities, in which the articulation between the ideas and behavior of societies is constrained by material construction, this may also mean that designing for change takes a larger place in their governance and material structure.

And finally, at the global level, we will have to find ways to harness the added information-processing capacity rather than let it dictate the future of our societies. That can only be achieved by a closer interaction between human and electronic information processing, and by using the power of electronic processing in novel ways, rather than to simply accelerate current, precomputer kinds of procedures. For example, we could move away from the reductionist statistical approach to interpreting massive data and gear our computers to truly predict rather than explain.

All this leaves us with a question about our role as scientists. First of all, I think we have to accept that the trust in science, in many of our societies, has suffered and is declining because of overpromising on the part of scientists, unintended negative consequences of certain inventions, and in a more general sense the harnessing of science by industry (for innovation) and government (to justify unpopular decisions). To counter this, we have to reconsider the institutional context of science, its engagement with civil society, and its presumed – but fake – neutrality. After all, our methods may be objective, but the questions we ask are subjective and culturally determined. We have to shift focus from a posteriori science (focused on origins and ex-post explanations of how we got to this point) to a priori science (focused on emergence of new phenomena in the past, in the present, and in the future), and this entails a shift to Complex Systems Science, with the implications outlined in Chapter 7.

Finally, a last but essential point on this issue. As scientists, we must be ready to engage in society. We are citizens trained in science but citizens above all. Hence, we should play our role in guiding society. Rather than limit ourselves to presenting the conclusions of our analyses in the most balanced detail – for and against – we can, and must, share with society our ideas about possible challenges and solutions to the problems it faces. But we must separate the presentation of our science from that of our conclusions and opinions, so that it is crystal clear what is what.

In Chapter 20, I presented some examples of the very wide range of visions for our future that are extant in the literature. The main purpose of those presentations was to draw the reader's attention to:

1 The challenges and issues involved in trying to stop the frantic race of our society to the destruction of our environment since

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developed societies have become subservient to economies, let alone any efforts to turn the clock back on the recent history of our societies.

2 The strong western cultural ("progress") bias involved in such projects as implementing the United Nations' Sustainable Development Goals (SDGs), a bias that might endanger the project itself because by the time (2030 or 2050) that the work is supposed to be done, many major societies in our world possibly will have very different cultural values than those on which the SDG project is based. The SDGs remain framed around traditional conceptions of economic growth, which are in turn embedded in the western economic progress vision, which has been adopted by most of the world's governments. But underlying value conflicts are sure to impede their implementation, and top-down implementation may exacerbate those value conflicts, cause conservative cultural backlashes, etc.

3 The observation that continuing to globalize large parts of the world is in all probability not an effective way to try and master the challenges our socioenvironmental systems are facing, even if it sometimes seems as if the rapid developments in information processing would enable a global government. On the contrary, ICT developments seem to point to a fragmentation of world regulation and governance into a multipolar system, thus avoiding hypercoherence and introducing a flexibility that takes local circumstances and cultural values into account.

4 A range of innovations in our ways of thinking and organizing ourselves that are the result of intensive interaction between human and electronic means of information processing. One of the interesting things is that these proposed changes, outlined in a recent volume by Ito and Howe (2016), converge substantially with the earlier chapters of the book, which were developed and written before I was alerted to it.

What Are the Chances of Success?

After lectures on the topics at the core of this book, I am often asked whether I am an optimist or a pessimist about the chance that human societies will survive the sustainability challenge. The question can be answered in many different ways. One of the simplest, which I often use after a long meeting, is that I am a long-term optimist as well as

a short-term pessimist. The long-term perspective that is mine as an archaeologist shows that, until now, humanity has always been able to change its ways of thinking and acting when it has been forced to do so. But in the process of implementing those changes, there has often been considerable short-term collateral damage (as my US colleagues and friends would put it).

What brings me to this conclusion? If I begin with the short-term pessimism, it is rooted in the extent to which the global market-based system, and more importantly its ideology, ethics, institutions, and attitudes, have rolled over much of the world and are embedded in very powerful social and economic structures. The struggle to reduce CO_2 and other greenhouse gases in the atmosphere, which is only one of the many consequences – rather than a cause – of the sustainability predicament we are in, shows us how difficult it is to change the course of our mammoth current socioeconomic (or should I say econosocial?) thinking and its institutional structure. If we succeed (and there are increasingly many signs pointing in that direction) it will have taken the world some sixty or more years, and yet we have not in any way dealt with the root causes of the problem. These may manifest themselves in a plethora of different crises to come, in virtually any domain we can think of: health pandemics, resource shortages, deterioration of the quantity and quality of the basic necessities of life such as food, clean air, and water, economic and financial crises, political instability, and so on. Unanticipated consequences of the increasingly rapid rate of innovation we have seen since *c.* 1750 in all domains is likely to overwhelm us in each of these – and many other – areas because our current global dynamic flow structure is simply unsustainable. Add to this the completely unpredictable but profound consequences of the ICT revolution, and it is easy to see that our global system has been at the edge of chaos, and is likely to be overwhelmed, if we let it continue on its current trajectory.

We effectively have to move our focus from progress, growth, competition, and individual satisfaction to community building, stimulating social (group) coherence, and multidimensional wellbeing. As expressed by Quinn in his magnificent novel *Ishmael*, we have to move globally from a taking to a leaving philosophy (1995). Many authors, including Daly and Latouche who were extensively discussed in Chapter 20, have been proposing this for some time, ever since Malthus raised the underlying issue – the positive feedback cycle between demography and food production. But we have thus far set hardly any steps in that direction, except at the level of individuals and some small communities.

This move implies breaking the fundamental feedback loop that I have put forward as the driver of human coevolution, linking information, cognition, innovation, energy, and population size. There seem to me at present several ways in which such a break could theoretically occur, but only a few that have a realistic chance to occur during this century. I will look at the potential of each of these in turn.

Breaking the Fundamental Feedback Loop of Coevolution

Now let us look at potential reasons for long-term optimism. Clearly, a voluntary reduction in population increase worldwide is difficult to put in place and has a number of consequences that are contrary to our current western (and increasingly dominant) value systems. Governments in China and India have tried to reduce the rate of population increase, in China forcibly and in India by a mixture of enticement and enforcement, but with mixed results. In both cases the greatest challenge seems to be the emphasis on economic growth, as growing economies generally require demographic growth in order to sustain themselves. The only other road to reduction of population that has been widely discussed is a major increase in per capita wealth in the developing countries, which, according to demographers, would reduce the birthrate in those countries. But one may question whether that would indeed have the desired long-term effect if one looks closely at what has happened in the developed countries, where, over centuries and millennia the population has seen major increases, interrupted by relatively short periods of stagnation or depopulation. Moreover, population reduction is a kind of "sacred cow" in developed countries – a basic infraction on a fundamental individual freedom that is not often publicly discussed. Convincing people to voluntarily reduce the number of their children requires convincing them to fundamentally change many of their values. This leaves involuntary reduction of the population owing to environmental or natural factors, such as pandemics, famines, and similar drastic events, which while deplorable are highly likely to continue. But these are also in disagreement with the philosophy of developed societies and are therefore likely to be resisted (owing to efforts in the domain of health) or mitigated (by means of food transfers). Viewed over the long term, this poses the question whether the wealth accrued by the developed nations will continue to be sufficient to keep successfully fighting off such events. Wealth, we must remind ourselves, that is accrued by exploiting the resources of the developing world.

Another way to interrupt the fundamental positive feedback loop that drives the current socioenvironmental coevolution is by limiting the energy flow through society that, as we have seen, is the inherent counterpart of the information flow. The acceleration of innovation and information flow that was triggered by the discovery and harnessing of fossil energy could conceivably be slowed down or even inverted by a lack of energy. However, one of the consequences of the greenhouse gas debate has been the shift to solar and wind energy that, once complete, ensures the long-term availability of plentiful energy.

This leaves other material flows as potential interruptors of the basic feedback loop. In discussing the topic, we have to distinguish between the availability of the means to meet basic human needs such as food and water and the availability of other raw materials, as used in industry or for shelter. Certain of the latter are, at one point or another, likely to run out: rare earth minerals, such as coltan, etc. But it would seem that human ingenuity and a sufficient investment in research will find solutions for such shortages by substitution.

Potential global shortages of food and water are more difficult to deal with, and until food security has been dealt with as a global challenge we do not know whether human ingenuity and will can solve this. One of the important constraints to increasing the total global quantity of food is the fact that human beings have a limited range of foodstuffs that they digest and use. Shifting the emphasis of production from meat and fish to vegetarian foodstuffs can reduce the risk of global food shortages for a (considerable) time, but some proteins are needed for human health.

Fresh water is another commodity that is basic to human subsistence. It, too, is limited in overall quantity available, especially if climate change leads to a reduction in the amounts of frozen fresh water available worldwide. Although it can be created from salt water (and there is enough of that), this is costly in energy, and there has so far been no major breakthrough in the water–food–energy nexus that I know of. Hence these two commodities may well turn out to limit the fundamental feedback loop unless per capita water use can be drastically reduced, particularly in agriculture (the heaviest consumer of fresh water), or water recycling can be improved and spread to the extent necessary to rely on available water resources. But this again is costly in (renewable) energy.

That leaves only one other potential human-engineered interruption in the basic feedback cycle: the information flow itself. Can we intervene in the data–information–knowledge cycle that is at the core of the flow structure that is driving societal coevolution? In the light of the ICT

revolution this seems an intriguing option that we need to consider in some more detail. One major difference with the other elements in the flow structure is that this one is driven by a very small, though growing, number of people worldwide. One question is whether that community could be convinced of the need to redirect its efforts in a different direction, and another whether it is not already too late to do so in a way that will convince others to take up their torch. But convincing a relatively small community seems easier to do than convincing a substantive part of the world population. I argued in Chapter 19 that to redirect the development of ICT away from a very small and powerful component of the world's business community, people in the developed nations need to reassert their individual and collective power to determine their future and control the development of information technology. Is that feasible? Will enough people come to see and accept the changes that this development is imposing on our social lives if nothing is done to wrest the control over it from those who have it at present?

A similar, relatively small but hugely controlling group that could at least theoretically be convinced to steer society in a different direction is the world of finance. The same questions will need to be asked and answered for this group, but at the present time there is more of a reaction to its supremacy than to that of the information technology (IT) community.

The next question is in which directions the current rapid developments in IT and/or finance could be reoriented to have a positive effect. The answer is in part the same: by strengthening public governance, they could be slowed down and then transformed so that large numbers of people across the world are empowered to use them in alternative ways. Widening out our value space with the values of the "developing" or "underdeveloped" world would not only enrich our experience, but also set in motion new dissipative flows, ultimately possibly balancing the existing inward flows of matter and energy, and thus spreading wealth rather than concentrating it.

How might this work? The ICT revolution will continue to impact on our society in very many ways that we can only glimpse at present. We must look at these both from the ICT perspective itself, and from that of its impact on our societies. From the ICT perspective, the technology offers the opportunity to mitigate at least to some extent the main cognitive limitations that we have mentioned earlier as driving societal information processing to date. ICT may improve the integration between human and electronic information processing. This is clearly an ongoing

process, in which exploiting the capacity of ICT to reach out and create horizontal networks of information processing worldwide is of major importance if we are to drastically improve the total information processing capacity of our societies. That will no doubt lead to different perspectives on our past, present, and future trajectories and, we may hope, a more realistic assessment of the long-term affordances and constraints of societal development. It will in my opinion also be one of the drivers of the enlargement of our global value space, and therefore an important driver of the transition from a resource-to-waste economy to an economy of opportunity that finds a better balance between "takers" and "leavers" (Quinn 1995).

ICT may also enable us to deal with the bias of human decision-making toward theories, ideas, and behavior that is principally based on successful past responses, owing to the underdetermination of our ideas by our observations. The big data revolution may enhance the role of observations in decision-making and therefore loosen the path dependency of our current societal evolution, paving the way for a very different kind of decision-making. Currently, techniques and methods to deal with that big data revolution are still insufficiently available, but the development of machine leaning is likely to remedy that.

In order to facilitate thinking about the future, ICT may help us develop a kind of informatics that, rather than reducing the dimensionality of big data into simpler concepts, does the reverse: moving from a limited number of observed dimensions to generate as many other dimensions as possible, and then testing those for feasibility, in effect reversing Occam's razor and assuming that the world is complex; and that, therefore, ideas need to embrace that complexity rather than simplify it away.

From a perspective of societal change, at least four different dimensions of the future impact of ICT seem important to me. ICT might (1) substantially increase transaction efficiency and (2) trigger structural changes in the division of labor, including increasing specialization in the functions and tasks fulfilled by individuals, groups, and institutions. As part of that process it may well render large parts of the population unemployed and therefore restless for change. That might in turn (3) change the configuration of our institutions, including firms and markets, as well as their roles and shapes. And, as importantly, (4) the fact that fewer resources might be devoted to maintaining the current structure would free up resources for implementing innovations.

These profound changes may in my opinion offer an occasion to move the long-term dynamics of human development in a different direction.

The ICT revolution is already in the process of leveling information-processing and wealth differentials by enabling the strengthening of horizontal networks, as opposed to the vertical ones that have dominated our human information processing for so many centuries and created the current wealth-centered world and its material imbalances between different strata of the population and between different parts of the Earth.

Rather than accumulation, spreading of information is becoming, and should become much more, the main driver of the economy, and the tool to create wealth in other parts than the current developed world. This trend is the reason for the high current valuations of the social networks, which have discovered a fundamentally different, novel, way to profit from the existing information-processing differentials – rather than increasing them, they are making their profit from decreasing them. This favors an inversion from the current, predominantly extraction-to-waste economy (in terms of raw materials, but also human capital) into an economy of opportunity creation and spreading wealth, and substantively enlarges the total value space of the global community involved.

But, and I cannot emphasize this enough, we need to grasp the opportunities offered by the ICT revolution and not let them slip by uncontrolled. The enlarging of the value space is not going to happen if the spreading of information is used to propagate the current, narrow, material-, gross domestic product-, and consumption-focused western value system across the entirety of the planet. Indeed, we must use this occasion to do the inverse – to enhance the global value space by developing the many other values that are current among non-western societies: actively stimulating the emergence of novel dimensions of value from the embryonic state in which they currently exist, often (but not only) among small-scale societies. Certainly, biodiversity is an important aspect of sustainability, but so is cultural (value) diversity. Without cultural diversity to grow our value system, we will not be able to find ways to durably live peacefully with billions of people on Earth. Only by increasing the information-processing capacity, education, and wealth of the underprivileged can we redirect the current trend so as to approximate a more stable equilibrium.

We can distinguish two main kinds of information processing that currently link the developed and the developing world. The first aims for direct information transfer from the developed to the developing world and does not directly contribute to the expansion of our global value space, even though the confrontation between the ideas spread and local knowledge may generate innovation and new values. The second

approach, on the other hand, enables the development of local knowledge and the expansion of local wealth creation. Examples of the first are the facilitation of distant access to information from many different sources that was initiated by the search engines (Yahoo, Google, etc.), and then led to the development of specialized online encyclopedias such as Wikipedia, which not only assemble but also synthesize information. It is now entering a different stage with the emergence of online degrees at many universities and the Massive Open Online Courses (MOOCs) driven by major institutions such as MIT and Stanford. These enable anyone to study free of charge, or at lower cost than is traditional, anywhere in the world. They are spreading as ways are found to return to the educating institution a small percentage of the proceeds ultimately generated by the people thus educated. They are part of the "online revolution," which will in the next thirty years fundamentally transform the worldwide educational and societal landscape at all levels. In addition, there are many e-based tools that, even though they do not deliberately aim to educate, have very important educational components. These range from blogs to social networks to "serious" games that promote certain learning skills. In this domain, we may expect many more innovations that contribute to the transformation of the information-processing landscape.

Examples of the second kind abound, and have been spreading for fifty years under the impact of those non-governmental organizations that saw that providing local populations in poor countries with western knowledge or infrastructure was not always effective in enhancing their happiness, wealth, or autonomy, and did not have as immediate and long-lasting an effect as helping local populations use their existing talents. Developing the local recycling economies of the developing world is a good example. These use materials such as empty oil drums and crates, used tires, and the like to create pipelines, furniture, and baskets. They are a fundamental part of the local economy, providing jobs, spreading or accumulating knowledge, and reducing waste. Giving them access to world markets has been one way to promote them, as in the case of the South African production of decorative baskets from telephone wire. Another example of this kind of promotion of local developments has been the spread of microcredit to provide for the initial investments needed for local enterprises (which are doing things that are not done in the west) to emerge. This has been so successful that more recently microcredit lending has spread to poor areas in the developed world, such as parts of New York City.

This trend is positive, but it would greatly gain in importance if non-western societies would try to move in the direction of implementing their traditional values, directed at leaving in Quinn's sense, rather than western (taking) approaches, increasing their level of education and innovative capability in independent innovative ways. One characteristic of many indigenous leaving societies is that they have not developed an externalized, material-based value system to maintain their coherence, but have, as far as we can see, very intricate and subtle, high-dimensional, internalized, mental value systems. Dematerializing our western value systems might be an interesting way to proceed.

Decentralization, Disruption, and Chaos

Whether as a result of one of the potential top-down reorganizations proposed in the last sections, or as a result of a bottom-up societal change driven by social unrest owing to the tension between globalization and social exclusion (Munck 2004), the changes are likely to trigger major disruptions in our societies. This is where my short-term pessimism comes in again.

It is one of the tenets of the resilience community (Gunderson & Holling 2002) that the kind of longer-term development that we have seen over the last sixty or more years ultimately leads to rapidly increasing vulnerability to shocks. Once such shocks begin to generate cracks in the dynamic structure of the system, novel values and ideas, which could not previously express themselves, emerge. I would argue that that is in effect what we are beginning to see worldwide, as our world fragments from a bipolar into a multipolar one at all levels. This fragmentation is nothing but another manifestation of the fact that people are beginning to assume an increased responsibility for their own actions because they no longer feel comfortable with the current system. As this feeling spreads, their actions will increasingly be based on awareness of different sets of values, and deviate from the kind of "rational decisions" proposed by the free-market economics that only takes a very limited number of value dimensions into account. This is exactly the kind of development that favors the growth of the global value space that I have been arguing for. But in the process it may well dismantle at least the upper part of the current institutional structure that governs our societies, limiting the size of coherent, stable, social entities. The European Union for example, might disintegrate into its constituent nation-states, and the USA might deconstruct much of its federal superstructure and relegate major responsibilities to

the individual states. Similar processes could occur in China, an empire that is essentially a conglomerate of regional entities with major social, economic, and cultural differences. How far down such deconstruction would reach in our current societal and governance systems is an interesting question. One of my colleagues argues that it might well go as far as empowering major metropolitan areas at the expense of all larger sociopolitical units.

It is likely that all this would lead to a substantive period of chaos before a next set of more or less stable institutional solutions was identified and implemented. The longer our societies continue on the current trajectory, the more likely it is that in such a chaotic period many people will suffer substantively. The current chaos in the Near East and adjacent areas is a telling example, as is the situation in Africa that is causing the current migration crisis in Europe. Neither is likely to change unless there is a fundamental societal restructuring, and that will take a lot of time.

But that is where my optimism comes in again. At some point in time this restructuring will happen, if only because it is the fundamental nature of human beings to be social and individuals cannot survive alone. That is the lesson of the long-term perspective that archaeology offers, the study of the emergence, flourishing, and disintegration of all kinds of societal structures, from very small to very large, such as the Chinese, Persian, and Roman Empires. That is the reason I can be optimistic about humanity, yet pessimistic about our current way of life.