



Addressing Tipping Points for a Precarious Future

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Print publication date: 2013

Print ISBN-13: 9780197265536

Published to British Academy Scholarship Online: January 2014

DOI: 10.5871/bacad/9780197265536.001.0001

Metaphors and Systemic Change

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DOI:10.5871/bacad/9780197265536.003.0001

[-] Abstract and Keywords

Tipping points are metaphors of sudden change, of fear, of falling, of foreboding, and of failure. Tipping points are thresholds of tolerance, of bifurcation, and of transformation which are built into complex systems of transformation. Sudden change can arise from earth system phase changes (for example in the condition of ice, ocean acidity, drying of the tropical forests and the onset of monsoons). But they can also depict rapid shifts in geopolitics, local and regional conflicts, and in economic performance with implications for the well-being of societies all over the globe. The patterns of suddenness and aftermath of physical and socio-economic systems vary greatly. Tipping points can lead to unintended worsening, to induced vulnerabilities, to chaos and confusion in communication, and to the scope for restorative redirection. The scope for benign transformation is an intrinsic aspect of the tipping point metaphor.

Keywords: tipping points, earth systems science, bifurcations, thresholds, predictions, well-being, vulnerabilities, metaphors

Setting the scene

This chapter has its origins in an introduction to a seminar jointly convened through the funding kindness of the British Academy and the Royal Society. Its purpose was to explore the various meanings and possible consequences of 'tipping points' over the coming decades. The seminar took place in the spring of 2011 at the Kavli Centre run by the Royal Society. It comprised ten speakers and twenty-five commentators. Participants represented a wide range of backgrounds, covering Earth system science, natural resource policies, economics, politics, media and communications, international relations, business, literature, and religion. What was fascinating was their enthusiasm for the creative fusion of highly diverse contributions and ideas. Participants embraced the wide range of meanings associated with 'tipping points' and grasped the significance of the concept for the disturbing age in which we find ourselves.

This introductory chapter surveys various ways of approaching and interpreting tipping points, and explains the contexts in which the contributions that follow fit into this framework. Thus, it seeks to provide a perspective for the whole book.

We took as our starting point the idea that tipping points are perhaps best understood as metaphors to help deal with uncertainty and complexity, wholeness, and the unpredictability of the future. Tipping points are processes of discontinuous, and at times disruptive, change. Generically they are *critical thresholds*, which offer various timescales of onset and impact. These thresholds may manifest themselves across the whole globe, or regionally, or locally. They can come in the form of planetary processes, of ecosystem adjustments, of military, terrorist, or convulsive **(p.4)** political action, or of profound shifts in economic performance, cultural outlooks and social behaviour. Indeed, tipping points can arise out of combinations of physical and social systems and the strains and stresses affecting them, all working in complex loops of influence and impact. What concerns us here, and in our concluding chapter (8.1), is that tipping points may sit at the cusp of being transformational for the worsening or bettering of human existence. 'Tipping points' in this book actually refer to a series of transitions and transformations, some predictable and some unforeseeable.

Three ways in which tipping points can be characterized relate to:

- The science of global physical systems, their measurement and predictability, singly or in combination, as addressed by Tim Lenton in Part 2;
- The social science of governance through means of anticipating and adapting to possible shifts in such system states, approached in Parts 4, 6, and 7;
- The creative processes of constructing ways forward for society, which contribute to betterment and accommodation, by procedures which are socially fair, build resilience through adaptation, and reinforce the fundamental integrity of the ecosystem life-support processes, explored in Parts 5, 6, 7, and 8.

Lying behind this framing of tipping points are four sets of propositions. The first is that we could be entering a time in which *unintended worsening* of policy makes for a drastic worsening of environmental problems and socio-economic conditions. By our particular ways of governing ourselves, we may be creating conditions of economy, of decision bias, of social conditioning, and of ethics which actually reinforce (lock in) the likelihood of tipping points in both physical and social realms.

Second, we could be creating conditions of *induced vulnerabilities* - the generation of further risks - through tendencies already apparent in policy, production and consumption. The ways in which we seek to adapt, because of this inbuilt tendency to create greater tensions (dependency, powerlessness, incapacity to adapt), can also lead to more intense and unanticipated combinations of both social and physical/ecological stresses.

Third, the uncertainties surrounding the idea of tipping points and their manifestations raise the problem of *incoherence* in communication and response. We have yet to consider suitable means for explaining the various narratives, or ways of visualizing and instilling meaning to tipping points **(p.5)** in all of their manifestations, which could lead to constructive adaptation and collective mitigation (as examined in Part 7).

Our final proposition is that tipping points must be conceived not only as risks and threats, but also as potential moments of *restorative redirection*. It is still possible for a series of positive transformational tipping points to be combined. These would prepare society for forms of governing, of designing economies, and of creating the social conditions for combined preventative action that can stave off the ‘malign’ tipping points, in favour of robust, resilient and adaptive values and governing procedures. This would be the creative and ‘super-adjusting’ tipping point, of which, at present, we see only glimpses – in social movements of ecological localism, and in many parts of developing economies where continuous resilience and adaptation are essential.

Achieving restorative redirection presents an immense challenge, but it is an experience which the planet has been through several times before, admittedly without conscious steering (Duarte Santos 2011; Lenton and Watson 2011). This particular transition will be hugely different. It will involve both profound shifts in social outlooks and associated adjustments. It will also require collectively agreed recognition and capacity to restore and nurture life-support processes, often under conditions of unfriendly and unbending economic incentives, and inbuilt vulnerabilities. Hence the shift towards so-called ‘benign’ tipping points, as ‘malign’ tipping points continue to engulf us, will neither be easy, nor in the absence of ingenuity and extremely determined and creative leadership, democratically popular. We only see tough times ahead.

Tipping points as metaphors

Metaphors can elicit new concepts by ‘throwing together’ pre-existing lines of thought into fresh perspectives, as Giles Foden argues in Chapter 3.1. Metaphors are conveyors of meaning and storytelling. Metaphors enable imagery and ideas to fuse and to recombine, to unify through experimental exploration. Shifts in manners of thinking and of meanings of values are easier to explore through metaphor. They allow continuous rediscovery from any starting point, especially where there are many possible endings. Metaphors stimulate the imagination, and loosen the mental bounds that restrict our perception of actual and potential realities. But metaphors can also confuse, because meanings are not always aligned to appreciate their **(p.6)** novelty. Metaphors may be contested and unruly, trampling on established patterns of thought and analysis. As a consequence, the science of tipping points (Part 2) and the politics (Part 6) are beset with conflicting interpretations as metaphorical pathways collide.

Metaphors may be created on the basis of past evidence, interactive models, creative interpretations of futures, simplifications of complexity, exploration of intriguing mathematical formulations, storytelling, and popular, misguided and sloppy usage. All these devices are means for characterizing, and giving shape to, uncertainty, interdependence, turbulence, and crises, and for unleashing the creative power of imagining. Metaphors are employed to assist in the ordering of chaos, for carving out meaningful narratives and stories from apparently seamless continuity, for creating understanding through patterns of skilful construction, and for firming up the shifting sands of unpredictability in order to obtain plausible assurance about what could happen next.

Three classes of tipping point and related metaphors attracted the attention of the seminar participants.

1. Threshold conditions, chaotic transformations, bifurcations, and revolutions

These are qualities found in mathematics; risk theory; catastrophe theory; abrupt change dynamics; the coupling of systems to sudden phase changes in local environments, macro-scale Earth systems, and in geopolitical outlooks. Such transformations take place in a variety of

circumstances: from stress points found in pathways of order and reason; to sudden shifts of political arrangements; to new patterns of power; to innovative processes of measurement and making choices. They are characterized by intervening periods of adjustment, which eventually reach a stage where inbuilt procedures for accommodation, or protecting existing institutions of decision taking, can no longer rely on 'more of the same'. Things simply have to shift.

Physicists, mathematicians, ecologists, epidemiologists and sociologists, in their various ways, have identified 'bifurcations'. These are points where a small additional 'forcing' or 'nudge' takes a complex system abruptly into a qualitatively different state or into the orbit of another system or set of properties in the environment, known as an 'attractor'. The interesting quality here is their apparent unpredictability, even though after a 'change event', it may be possible to spot the clues of onset. In the arena of political transformation, for example, the fall of communism in the early 1990s, and **(p.7)** the 'Arab Spring' of 2011 have been analysed for their precursors in the internal social and political dynamics of restless and networked societies, and oppressive regimes. Tipping points are rarely wholly unpredictable. There is currently much excitement about the prospects for early warning of such 'critical transitions' in a range of complex systems (Scheffer 2009), and perhaps even on the basis of identification of large-scale recurrent patterns in social evolution and upheavals (Turchin and Nefedov 2009; Turchin 2011).

2. Prediction, adaptation, resilience, accommodation, path dependency, and tenacity in holding on to the familiar

These are all variants of responses to confronting or actually experiencing such threshold conditions. Doing nothing is not considered a viable or sensible option, but any sudden shifts of policy or behaviour carry all manner of risks and potential casualties, and any new rules of decision taking are usually unfamiliar and weakly formulated. Changing tardily patterns of power, clinging on to conceptions of morality and fairness, and relying on the process of 'muddling through', all play their part. So too does the tendency to cling to existing commitments of political dependence, or the failure to adapt because too much sunk investment is at stake.

One cause of the collapse of earlier civilizations might have been the unwieldy scale of large urban complexes, and the associated stubborn adherence to living with the 'sunk costs' of existing, costly, and inflexible infrastructural investments (Scheffer 2009). But 'sunk costs' also apply to political power structures, worldviews, and frighteningly interdependent economic institutions. This applies today in cases such as the banks, particularly in the Eurozone countries. A related but uniquely frustrating phenomenon of 'systems that fail to tip' can be found in political and economic crises where nearly everyone agrees that something has to give (see Sara Parkin (6.3)). Tim Lang and John Ingram (4.1) offer an equivalent perspective on the increasing elusiveness of food security.

The very nature of nascent tipping points makes it difficult to shift attitudes, values and behaviour. Tipping points are visible clearly, if at all, only in the historical record, and thus lack compelling force in the present. The overwhelming temptation and pressures are to wait and see, to hope that something turns up to eliminate the projected risk, and to enable business as usual to persist, or to assume that we can always fall back on adaptation.

(p.8) Note, however, that even adaptation does not always result in positive coping. Ill-designed adaptation can reinforce vulnerability and the brittleness of power and authority, unsuited to emerging threshold conditions, where established mechanisms for adaptation and adjustment can no longer hold. Emily Boyd (7.2) points out that weak adaptation, even in the

face of crisis, may arise from the mixing of informal social preferences and cultural norms with formal and less flexible political and economic institutions, further muddled by clumsy media and communications misunderstandings. Adaptive governance, she notes, 'consists of four fundamentals: explicit understanding of the system; monitoring; flexibility in management and administration through networks; and preparation for "surprise"'.

3. Social construction, opportunism, media formulation, marketing, and organising bias

Tipping points are now invoked in all manner of publications, of communications, of language and knowledge, almost whenever the notion of threat, of crisis, of fear, of helplessness, and of a call for dramatic transformational approaches to the messy governing of economies and societies, is called upon. Here the notion of tipping points loses its shape, tends to be overused and blurred, and hence can become unhelpful as a narrative for coping. This is precisely the danger of metaphor which Giles Foden counsels against in Chapter 3.1. The tendency for universality, for sloppy comparison, and for meaningless preparation, may yet prove the nemesis of the tipping point metaphor. Metaphors can guide, but they can also muddle. This aspect is explored by Tim Lang and John Ingram (4.1), and by Patricia Howard (4.2) in her various ecological, cultural and linguistic interpretations of biodiversity. Tipping points, like the highly necessary but deeply contested concept of sustainability, are already in danger of being over-defined, chaotically misinterpreted, and chronically abused by overreliance on ubiquitousness.

A sense of foreboding

Lying beneath these formulations of tipping points is a sense of foreboding. We appear to be entering a stage in world affairs where rapid change, spurred by instant communication and an overwhelming desire to dramatize events to gain competitive media attention, appears convulsive, **(p.9)** cataclysmic, and beyond any sense of benign rational management. It is so tempting to ignore warnings, to cling on to the familiar, to hold on to sunk investments, and to seek pathways which are already damaged by protective power and false promises. This is particularly so in the many cases where the timing of possibly tragic outcomes is not provable, and is subject to very wide variations in estimates. Denial, delay, and dissonance capture the desperation of hanging on.

The emerging worlds of interconnected systems dynamics, and the sweet fruits of interdisciplinarity, tempt thinkers to try and understand our predicament by modelling it. Modelling with huge banks of data is now possible on scales almost unimaginable a decade ago. There seems to be no limit to the scope for amassing meaningful patterns from seemingly chaotic cascades of information, apart from the imagination needed to create and make sense of these patterns. And the more the requirement to organize and give meaning, the more there needs to be fusion of both a narrative for creative exploration and a model for analytical ordering and forecasting. Yet the very capacity of modelling nowadays draws our attention to the significant voids in data arrays. For example, ocean acidification may or may not be catastrophic, not just hazardous, for calcareous marine life: we do not yet have the necessary instrumentation or the time series trends to be sure.

Such modelling is now so sophisticated that it can encompass both physical and social systems, and can combine the talents of academia, business and government. So the scope for extraordinary integration between disciplines, and means of shaping innovative decisions, is becoming very exciting. Here the mathematics and the narrative can be combined creatively. Tipping points could be expressions of wholly new forms of reasoning and imagining, of cross-cultural communication, and of preparing for fundamentally fresh ways to discover the

'complete human condition' in an age of real threat to the betterment of all life on this beleaguered planet. Novel forms of communication, such as those advancing on social networks, offer ways to translate the metaphors of thresholds and scenarios. Joe Smith (7.1) and Paul Brown (7.3) show that there are fundamental difficulties in conveying the power and authority of tipping points.

Furthermore, we may be experiencing in the emerging decade a new kind of geopolitics. There is the prospect of a radically different world order, a period of increasing instability for a growing number in unpopular dictatorships, of unprecedented growth of middle-class consumption (**p.10**) in the emerging economies of China, India and Brazil, of massive social costs of ageing and concomitant under-representation of support workers, and, in recent times, an unusual and possible dangerous decline of accustomed affluence for many households in nations with established democracies. The ever-widening gaps between economic and social privilege and disadvantage, and the consequent deep democratic frustration combined with widespread sense of impotence – surely unwelcome hallmarks of this decade – will add to this instability (Turchin 2011).

Lying behind our contemplation of tipping points could just possibly be the most turbulent prospect facing the global human community in its existence, as covered in Part 8. The futures hinted in the discourses of tipping points could cover peaceful survival, completely new forms of learning and understanding, quite radical forms of communicating, and very different modes of enterprise and betterment for the whole of the human family. Laurence Freeman in Chapter 5.1 introduces *contemplative consciousness* as a means for combining wholeness with detachment, belief and faith, science with ethics. He offers a simple but powerful meditative framework for positive transitions.

On thresholds and bifurcations

For almost 200 years, classical physics, mathematics, and social sciences seemed to accept that change was smooth. Yet underlying the notion of continuity and positive readjustment, were formulations of exponential growth, with its characteristics of doubling times and rapid alteration. Mathematicians call the outcome a 'singularity', namely a point where the equations give results that tend to infinity. This too has become a metaphor for a grand tipping point, that imagined by Kurzweil (2005) as the transformation of human society and economy by mid-century through what he takes to be exponential advances in technology, data-processing power and artificial intelligence. The patterns of both smooth change and disruptive discontinuity create unstable rhythms where the characteristics of the system in question become radically different in function and structure.

When a state departs from its predicted path, on to some other trajectory, it is said to 'bifurcate'. This notion has been used in chaos theory to show that small shifts in initiating conditions, which may not even be observable, can lead to radically different outcomes. Earth system dynamics, such (**p.11**) as those dictating monsoonal patterns, locations and timing, or abrupt changes in forest water availability and drought-induced burning – all these express disequilibrium, with hierarchies of dynamics and outcomes which can be modelled, but where the modelling also requires large doses of creative intelligence.

In ecological systems, such thresholds can be depicted as points, or as zones of interruption in a prolonged transition. The 'point' notion is more common, since there are many examples of sudden shifts in ecological conditions arising from very small additional changes. One oft-quoted example lies in nutrient enrichment or eutrophication of shallow lakes, where a pattern of low-

nutrient status with particular plant diversity can switch abruptly to a high-nutrient low-diversity pattern. Many more examples of ecological tipping points can be found in the recent literature (Barnosky *et al.* 2012; UNEP 2012) and the Resilience Alliance and Santa Fe Institute thresholds database (Resilience Alliance 2004).

'Hysteresis' is a term reflecting the level of dependence of any system state on its history. It is possible for a change to be reversible, but the return to the original state will almost always be at a very different point from the initiating conditions of change. Thus coastal salt marsh, removed due to the squeezing of the coastline caused by a combination of rising sea levels and the construction of tide-protecting seawalls, is proving extremely difficult to re-create. This is one of the factors behind the economics of sharing with nature, namely the potentially huge cost of restoring lost eco-functions, either by human-made arrangements or lengthy and expensive repair.

'Panarchy' is one characterization of the relationship between thresholds in natural states and adjustments in human management arrangements (Gunderson and Holling 2002). Toby Gardner (4.3) considers how the lengthening dry season in the Amazon rainforest could result in whole new patterns of water resource care and reforestation, just to ensure that the rainforest communities have sufficient water for human and commercial consumption in the years to come. Meanwhile in the boreal forest, warming and drying weakens the natural resistance of trees, rendering them susceptible to pest infections. Pests are strengthened and more dispersed due in part to climate change. These are instances of combinational thresholds, which place special strains on the adaptive capabilities of human response.

There is much interest amongst ecosystem modellers over the changing rates of return to earlier population states following some disruption, such **(p.12)** as drought or cold, or loss of feeding availability. It is possible to measure patterns of 'loss of resilience' in some of these adjustments so that early indicators of incipient stress can be identified and monitored. This is part of the bifurcation approach to modelling, which relies on precursors to possible thresholds of altered conditions. Research on the drying of the Amazon rainforest, and associated incidence of ground-litter fires, is making use of this approach, as Toby Gardner (4.3) notes. However, the metaphor allusion is still relevant, as the range of data over time and space may not be sufficient for reliable measurements to be made meaningful, except through the metaphor process.

More attention needs to be paid to inter-linkages, to much more interdisciplinarity between physical and ecological processes and human interpretation and behaviour, and to localness of action. This is the message of the Amazonian drying and burning, as pointed out by Toby Gardner (4.3) and Patricia Howard (4.2). It is a function of accumulating local decisions, connected to regional climate change effects, and it can best be addressed through connecting local initiatives which are comfortable to local cultures, even though the whole response needs to have the form and shape of joint regional cohesion. Such arrangements are not easy to put into effect, but will be given expression in our final chapter (8.1).

On appropriate metaphors for social transformation

It is by no means so easy to follow the threshold/bifurcation metaphor for social systems. Paul Ekins (6.2), Sara Parkin (6.3) and Tim Lang and John Ingram (4.1) adopt this position. Social changes are not readily characterized by flows and patterns, as they are so infused with histories of culture, power and institutional rigidities. Despite the wish of policymakers and chief executives to imagine a world where it would be possible to predict an outcome from a given set of causal agents and behavioural variables, this is not in the socio-economic purview. (For a

qualified defence of the case for prediction in social science based on such modelling of agents and variables, see Turchin 2011.) And there is no model of mass action which can show that if sufficient people change their behaviour in a certain way, then a predictable outcome, say for carbon reduction, or household water consumption, will follow. This suggests that the tipping point metaphor is inescapably qualitative, at least given our current and prospective knowledge of ecosystems, economies and societal evolution, **(p.13)** and thus unsuitable for serious adaptation in governance, and all too dependent on creative imagining and empathy. Such characteristics do not commend themselves to policymakers and business leaders, who prefer quantitative models, no matter how ill-founded or even bogus, with some estimation of riskiness.

In the socio-ecological systems realm, therefore, it is naive to visualize any possible transitional condition, or possible precursor bifurcation, as having some kind of objective independent existence. Social phenomena are shot through with learning and forgetting, commitments to existing power and decisional arrangements, and plain cussedness. There is therefore a deep conceptual weakness in the translation of ecosystem analysis of threshold metaphors to governance generally, and to human behaviour more typically.

Resilience seems to be a concept more attuned to ecosystems functioning. To transfer it to governing arrangements and social systems brings in all manner of non-measurable phenomena such as equity, foresight, learning capabilities, scales of action, path determinacy of previous institutional commitments and 'mindsets', and wilful denial. Business and market mindsets, and the political realities of grappling with 'wicked problems', where the 'boxes are too difficult to tick' (see Charles Clarke (6.7)), lead to insecure action and to mindful delay. Nevertheless, we live in a coupled world of human-nature interrelationships (Ostrom 2009), so there is still merit in assessing just how human aspirations in favour of manageable survival and reduction of avoidable threat can be channelled on to the threshold metaphor.

It is possible that the second group of tipping points (induced vulnerabilities) is beginning to accelerate and amplify the onset and severity of the first (unintended worsening). If so, human resilience and acquired adaptive capabilities may not be sufficiently robust and flexible to cope. Tim Lang and John Ingram (4.1), for example, in their exploration of food security and attendant ecological ills, point out that the tipping point metaphor is less apposite than studies of raw power: of huge unaccountable corporations with limited foresight capacity; of complex governing rules and regulations which disguise and promote over-consumption; of misappropriated production, and chaotic pricing patterns; and where affordability and availability are working at cross purposes. In their analysis, tipping points are not metaphors but dysfunctional system conditions. Emily Boyd (7.2) echoes this dysfunctionality of system states. The economic/business/governance analysts led by Paul Ekins **(p.14)** (6.2) also acknowledge the evident and pervasive failure to foresee the foreseeable.

What emerges here is the notion of technological 'lock-in'. This is the tying down of technology and market forces into self-reinforcing patterns of continuation, a syndrome of 'path dependency' based on sunk costs, fear of stranded assets and unwillingness or inability to invest in major infrastructural change. This is very evident in the failure to remove carbon from the global economy, and in myriads of tiny decisions, from exploitation of new oil reserves in the warming Arctic, to the 'fracking' of shale-based oil and gas, to the enormous difficulty in achieving electric/ hydrogen filling points for more ubiquitous low-carbon fuel availability. The obverse of techno-lock is 'social-unlocking' - the scope for benign transformation, rooted in changes in values and social organization, as addressed in our final chapter (8.1).

More attention needs to be paid to the polycentric nature of responses beyond the level of the nation state (alone or in concert) (Ostrom 2009a). We need many kinds of sub-national and cross-sectoral responses, on the basis of a number of nations and other actors, such as city governments, NGOs, and corporations combining forces, creating the basis for networks of action on many different timescales and levels (Carley and Christie 2000). Addressing the 'governing region' in the evolving metaphor of tipping points requires much more attention than is now the case. This would apply to China and India and Brazil as well as the 'soon to be water-poor' neighbours of shrinking montane glaciers.

There may be an even greater need for preparing for tipping thresholds in this combinational form at very local levels. This is the focus of Part 8. There is much interest in the determinants of human behaviour and in the scope for cultural shifts in both habit formation and group outlooks and action. If we are eventually to get anywhere with adaptation and resilience to such groupings of tipping points, then these seemingly intractable arenas of imperfect learning and responsiveness will need to be addressed. As Laurence Freeman observes in Chapter 5.1, 'The virtue of hope is not putting the best spin on bad news or fiddling while the planet burns. It is a conviction that because of, and not despite the human element, an eventually positive outcome is always possible.'

(p.15) On resilience, adaptation and adjusting to the unfamiliar

If we can work through the various metaphors of thresholds, bifurcation, and convulsion, we need to address the complementary thresholds of adaptation, accommodation, and adjustment to the unfamiliar. In the climate change world, the Intergovernmental Panel on Climate Change regarded adaptation as having three purposes: to reduce exposure to known or possible hazard; to develop a capacity to cope with unavoidable damage (the costs which cannot be removed by reduced exposure); and to take advantage of new forms of living and governing so as to seek to redesign hazard or threat out of the system. The process of adaptation can be spontaneous, namely autonomous and reactive; or planned and managed through deliberate policy decisions and investments based on reasonable precaution or prediction; or anticipatory, in that there is a long-term process of accommodation of human activity and behaviour.

Emily Boyd (7.2) adopts the notion of four phases to adaptation in an adaptive cycle (Gunderson and Holling 2002):

- *rapid growth* (r) typically characterized by pioneer species, innovators or entrepreneurs;
- *conservation* (K) where resources are increasingly available and locked up in existing structures;
- *release* (omega) often triggered by a disturbance (e.g. fire, flood, disease) that exceeds the systems' capacity for resilience;
- *reorganization and renewal* (alpha) where invention, experimentation and re-assortment are common.

According to Boyd, the adaptive cycle has two opposing ways of operating. The rapid growth and conservation phases operate together as the 'front loop', while the release and reorganization phases form the 'back loop'. The front loop characterizes the development phase, and features activities such as the accumulation of capital, stability, accommodation and improvement. Empirical studies of complex adaptive systems often focus on gradual change, such as forest conservation operating on the front loop. Tipping points work is looking at the back loops, where

systems that are undergoing shock may result in a reorganization that maintains the essential character of the original system within the desired state, yet shifts thinking to new ways of framing, adapting to and governing climate shocks. Toby Gardner (4.3) on the drying of the Amazon provides an example here.

(p.16) Of interest here is the scope for merging the metaphors of thresholds with those of adjustment and anticipation. In almost all cases there is little institutional clarity for any meaningful and comprehensive approach to adaptation and the removal of vulnerability. Human patterns which rely on large settlements, now the dominant norm, are thus vulnerable to the confrontation of sheer inertia with the need for rapid adjustment. The possibility of parts of the West Antarctic ice sheet collapsing over a period of decades, with concomitant rises of sea level of a metre or more (unlikely but not unimaginable) would place megacities such as Shanghai, Dhaka, Jakarta and Mumbai in an adaptation crisis. There is at present no institutional machinery for dealing with the provision of food, fresh water, transport, or waste, to say nothing of relocation of many millions of people in many forms of supportive or fragmented community structures, in the timescale of a couple of decades. And to seek to do so whilst aiming at giving everyone the opportunity of adopting sustainable livelihoods is almost unimaginable.

The literature on collapse of earlier human settlement seems to focus on the role of adverse events (even when predictable); the excessive size of collapsing settlements; rapid population growth; competition for scarce privilege amongst elites; and evidence of over-exploitation of resource use immediately before catastrophic 'system failures'. All of this suggests that the metaphor of adjustment, either through planning/management, or by anticipation and pro-activity, may be very difficult to implement for resource-intensive, high-density, rapidly developing, increasingly unequal, and information-technology-dependent societies. Yet these are the very conditions being replicated on a daily basis.

So it is possible that we are creating the very elements of destabilizing bifurcations in our maladjusted adaptive responses which carry within them the seeds of tipping thresholds. The very act of simplification may be leading to emergent conditions of behaviour (for example, denial or resistance to innovation) which may lead to new unstable system states, and which profoundly affect the connections with other adaptive systems. This may be happening with the 'green growth' scenarios, where investments may not give rise to many new jobs because too many of the current unemployed are not suitably trained for such employment. We return to this in our final chapter (8.1).

(p.17) On social construction and opportunism

The third framing device we can use for approaching tipping points is that of social construction, the meaning and purpose of entertaining the concept at all. Here we enter the world of creative imagination and of new forms of constructing social relations and outlooks. Giles Foden (3.1) reminds us that stories are segments cut into the flow of time, sections of continuity which convey order and structure into what otherwise is chaos. This helps to bring the dimensions of space and time and causality to tipping points.

So another way to consider the metaphor is to think of tipping landscapes - of terrain where many different explorations of possible future states can take place, and where creativity and not just modelling from datasets can be fused with rational enquiry. This would require more training and exposure to many different models of learning. Game-playing, storytelling, scenario-exploring, new forms of measuring betterment, justice, and adaptation will be needed in the design of business management, public service training, and schooling. Being more comfortable

with the unfamiliar will become very important, as will cooperating in groups under circumstances of the unexpected and the removal of bias associated with sunk costs dependencies.

This will require a new approach to communicating future conditions. If people can begin to have the tools to imagine 'beneficial tipping landscapes' which reveal the strength of change and adaptation, but which are also underpinned by empathy, compassion, and virtuous responsibility (see Tim O'Riordan (6.1) and Joe Smith (7.1)), we may begin to create cultures of communication over tipping point metaphors which offer the incentive of hope, and hence the incentive for creative change.

This transformation may not be possible in present arrangements of social existence and economic development. Maybe current models of governing, of power relationships, of path dependency and of markets, convey inbuilt structures which critically impede such transformational narratives (Rist 2011). For us to be sure, we need to uncover the essence of governance and of markets, of cultures, and of diversity of living patterns, which can reveal just what bifurcations can be anticipated and designed, at least experimentally, just to see what is possible even in a world of impossibilities. These aspects are addressed in Part 6, both from a philosophical viewpoint of market immoralities, and from the hardheaded pragmatics of the business and political worlds.

(p.18) This will require leadership of quite an unusual kind. Leadership which is deviant from normal managing styles, where social enterprise of the more imaginative and experimental kind is permitted to emerge and to be tested and supported. Sara Parkin (6.3), Amanda Long (6.4) and John Elkington (6.6) give this aspect prominence in their contributions. Leadership means a willingness to accept the learning and adaptiveness of failure, both on an individual and collective level. This means making much more use of the modern communicating technologies of social networking so that people can talk to each other with inventiveness, imagination and experimentation, as suggested by Matthew Taylor (3.2). It is just possible that the technology of the emerging age will enable 'localism' within mega-structures to flourish, so that communities can design their capabilities and renewal in the spaces of their familiarity and comfort zones. The 'urban village' could come of age.

Good news stories

In all our consideration of the threats, risks and foreboding inherent in the study of tipping points, we may lose sight of the myriad 'good news stories' which are shining beacons across the face of the planet. We certainly need to hear of these and to learn from their successes and capacities for furtherance and repetition. Businesses are learning and responding, and we need to know more of these adventures. Communities are managing under the most amazingly adverse circumstances to create economic, ecological, and social resilience, and we need to know more of their achievements and why they persevere.

One such example is the aftermath of the 2010 Pakistan floods which afflicted over 20 million people and some 1.7 million homes. Emily Boyd (7.2) reveals the huge challenges of combining many aid and relief efforts with infrastructure and social capital investments on a vast scale. She concludes that there is no guarantee that even the combined weight of the international development banks, the various aid streams, and the resources of the aid charities can bring about sustainable livelihoods in the coming years. Responses in the aftermath of disaster may inform us more of better preparedness for adaptation to tipping points.

One optimistic arena is the emergence of the social entrepreneur with the capacity to make profit from socially and ecologically sustaining business. We certainly need to hear more about such entrepreneurs and **(p.19)** what forms of governing and market conditions, on a suitable geographical and cultural basis, might offer the best scope for their flourishing. John Elkington (6.6) has made a specialization of studying and advocating for this fascinating business niche. This in turn suggests a discussion on the appropriate models for businesses in facing tipping points/thresholds, again in a regional/local setting. There may well be a case for a more integrated approach to public/private/civil connections in future business models, with appropriate regulatory incentives to support them.

Laurence Freeman (5.1) reminds us that we are fearful of our mortality, that we do care about contributing knowingly to calamity, and that we can connect to the long term through devices such as meditation and opening of the mind. The ultimate metaphor may be what Freeman terms the 'inner eye'. This is the element of our imagination and awareness which transcends our normal reasoning. Triggering the inner eye may be the precursor to triggering the benign elements of addressing tipping points. This is a profound feature of anticipation, of alertness, and of recognizing the scale of the complexities before us.

Humble meditation may offer the beginning of visualizing the new horizons. Anthony Seldon (2011), Master of Winchester College, has initiated a period of stillness throughout his school for all beginnings of classes and meals. He regards stillness as a means to help young people to avoid responding to impulses. Pupils see immediate gains, but not the long-term consequences of their choices. Learning to be still, to cultivate mindfulness - and to think before acting - is thus not only a desirable, but also a key responsibility for education.

We cannot cope with tipping points with the outer eyes we use every day. Paul Ekins (6.2) shares this view. The markets and the financial arrangements do not appear to have an inner eye. Keith Clarke (6.5), speaking from a business perspective, says there is no far-sight in business unless it is regulated for. The critical elements of the modern economy do not yet contain this critical inner eye. Amanda Long (6.4), also a chief executive, is more optimistic. There is a glimmer of the creative visioning of the inner eye in the best of business leadership. Such 'good news stories' should be discovered and amplified. There is still just enough time to do this, as we explore in our final chapter (8.1).

So we begin our journey. Arguably critical thresholds are what spur us on. There is a long history of belief in catastrophic convulsions and ecological 'die-outs' in the planetary evolutionary journey. And the science of risk is peppered with associations of learning from hazard and **(p.20)** precaution. So we may have to experience the onset of tipping points simply to be 'shocked and awed'. This should not stop us right now from at least recognizing our follies and our institutional deficiencies. This is the context in which the chapters and commentaries unfold.

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