"Two Cultures": An African Perspective on the Emerging Intellectual Basis for Greater Cooperation between the Natural and Human Sciences in the 21st Century

Mark Swilling

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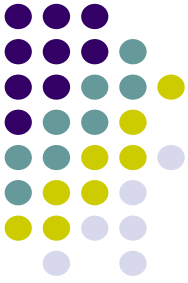

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Mark Swilling

Abstract

Ever since the Eurocentric Enlightenment, intellectuals educated within the Enlightenment tradition have debated the consequences of the separation of the natural and social sciences. However, the commitment to rationality, progress, universalism and reduction were common to both, mainly because the social sciences were imbued with the view that to be 'scientific', the social sciences needed to find ways of emulating the Newtonian scientific method in the social sciences. However, while the social sciences came to be dominated by this modernist impulse late into the 20th century, the natural sciences - starting with physics - started to discover the limits of modernist thinking and complexity theory emerged. As the 20th century drew to a close and Africa started to emerge from the lost decades of the post-colonial period, African intellectuals have had to find a mode of expression within a context where modernist certainties in both the natural and social sciences had collapsed. Furthermore, the challenge of sustainability was on the agenda as a constraining framework for developmentalism and the discovery of the origins of humanity in Africa had become orthodoxy. In many ways, the search for origins has become a way of finding clues for future survival as a species, while sustainability has become the key criterion for rethinking development in Africa. In order to provide a theoretical basis for meeting this ontological challenge, it is proposed that a new synthesis is required that transcends the modernist divisions between the natural and social sciences. It is suggested that complexity theory could provide a useful epistemic point of departure for achieving this synthesis. This, in turn, could pave the way for what Paul Ehrlich has called a new era of "conscious evolution".

About the author

Professor Mark Swilling is currently Academic Director of the Sustainability Institute and Head of the Division: Sustainable Development Planning and Management in the School of Public Management and Planning, University of Stellenbosch. Prior to this, he was an Executive Director of Spier Holdings (Pty) Ltd. He was a co-founder and then became the Director of the Graduate School of Public and Development Management at the University of the Witwatersrand, December 1995-April 1998. Before that, he helped found PLANACT in 1985, an urban development NGO based in Johannesburg.

Professor Swilling has published over 50 academic articles and four books and he has written extensively for the popular media on a wide range of public polity issues. He is currently writing a book with Eve Annecke entitled *No Closure: Sustainability from a Southern Perspective*.

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Mark Swilling

INTRODUCTION

C.P. Snow's famous 1959 Rede Lecture in the Senate House at Cambridge marked a decisive moment in the debate within Western intellectual culture about the nature of the relationship between the natural and social sciences at a time of high modernism (Snow 1993).

C.P. Snow's lecture became famous because it triggered a virulent debate about the chasm that existed at the time between the natural scientists and what he called the culture of the 'literary intellectuals', or what we might today call the English classics. But from the perspective of where we are today at the dawn of the c.21st, it was in fact a lecture that eulogized the promise of a science-based industrial modernity, and in particular the capacity of this Eurocentric conception of modernity to transform a world that he regarded as perilously divided between a rich north and a poor south. (In fact, four years later in a supplementary note to a republication of the 1959 lecture, he admitted that he had originally intended to title his lecture "The Rich and the Poor" since this "was what I intended to be the center of the whole argument" (ibid., p.53))

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[1] This paper is based on an opening address prepared for the Workshop on the Origins of Humanity and the Diffusion of Human Populations in Africa, September 17-19, Lanzerac Estate, Stellenbosch, Convened by the Human Sciences Research Council. A version of the paper is forthcoming in: Pieterse, E. and Meintjies, F. (eds) 2004. *Voices of Transition: The Politics, Poetics and Practices of Development*. Johannesburg: Heinemann.

Reflecting his social democratic inclinations, Snow fervently believed that the solution to global poverty was to transplant the Northern model of industrialization into the emerging developing world. To achieve this, however, a massive globalisation of (western) scientific knowledge would be required because, after all, it was this knowledge (together with the engineers and their toolkits of applied science) that drove this form of industrial modernity. The obstacle to achieving this, however, was the failure of the literary intellectuals to fully embrace modernity reflected in their ignorance of basic science. From this flowed his famous indictment of western intellectual culture: "So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their Neolithic ancestors would have had" (ibid., p.15).

C.P. Snow's 1959 critique of the "two cultures" was not in fact a call for its transcendence and synthesis, nor was there any place in either of these "two cultures" for anything other than western scientific and literary traditions. Instead it was a call for western literary intellectuals to bury once and for all their Romantic reservations about the materialism of western modernity and to fully embrace Newtonian science on the grounds that this would be in the interests of all humanity, especially those who live in the "poor countries".

It is a daunting task indeed to unpack the layers and layers of assumptions of this worldview from the perspective of an African intellectual perched as I am on the southern tip of Africa which is now generally accepted as the "cradle of humankind" and in September 2002 hosted the controversial *World Summit on Sustainable Development* – a summit on the future of the world that C.P. Snow so wanted to save. Some might even wonder whether this is a worthwhile endeavour at all. In my view, it is because C.P. Snow's worldview is part of our history. To find a new collaboration between the sciences and humanities that is appropriate to our specific context must entail both coming to terms with our past, and synthesizing something new. I will argue, however, that this will not be achieved via the now faded promise of Newtonian science which, contrary to C.P. Snow's great optimism, has not only collapsed as a paradigm, it never became the intellectual basis for a universal modernity of benefit to the poor. Instead, the challenge today is not the unleashing of scientific modernity, but rather it's containment

for the sake of a sustainable future. This, however, will require a very different kind of cultural synthesis to what C.P. Snow had in mind.

BEGINNINGS AND ENDS

The current high level of academic and popular interest in the story of our origins as a species is in my view intimately tied up with the desperate desire to determine whether our species also has a future. But what interests me is that both the search back in time for clues about where we came from, and the clumsy groping into the future for clues about what we need to do as a species to survive are forcing natural and social scientists to work together in unprecedented ways. It may therefore be possible to suggest that the intellectual basis for greater collaboration between the sciences and humanities in the c.21st may well be driven by the headlong contemporary rush to comprehend our beginnings and increasingly threatening ends.

If this contention is valid, then what I have suggested stands in polar opposition to C.P. Snow's 1959 worldview in two important respects. First, instead of the globalisation of a first world model of industrial modernity as the primary driver of greater socio-economic equity, the contemporary dynamic is equity via the search for sustainable development where industrialization and urbanization is constrained by severe limits to the carrying capacity of the natural systems within which these human systems are embedded. Unsurprisingly, C.P. Snow's world of the late 1950s was completely ignorant of the natural limits to modernity. The current consensus is that at least three more planets will be required for every person on earth to live like a middle class American.

Second, instead of a Eurocentric cultural synthesis of English classical literature and Newtonian science, we may well be talking about a geographically multi-nodal synthesis of post-Newtonian science and post-modern social theory where the irreducible uncertainties of complexity have replaced the quantitative certainties of Newton's basic laws of motion. To illustrate, imagine the following dialogue: instead of a Cambridge Science Professor writing a letter (in fountain pen) to the Professor of English Literature at Oxford to explain the Second Law of Thermodynamics in a C.P. Snow novel, we would now describe a Chilean geneticist working for Monsanto writing an email to her boyfriend the computer programmer from Bangalore in India about the successful use of

DNA testing methods to analyse a unique fossil recently discovered outside a South African seaside resort called Stilbaai.

I will devote the rest of this paper to a further elaboration of these two basic propositions. As far as the first proposition is concerned, I will suggest that sustainability is untenable without evolution. Put differently, if sustainability is really what we all hope will be a self-negating prophecy about a disastrous end to the survival of the human species as a whole on this earth (I say as a whole, because a significant proportion is not able to survive now), then evolution is the story not just of the human species, but of all life and therefore how dependent the human species is on all other life forms. I simply cannot fathom how it will be possible to contemplate building a global inter-disciplinary commitment to sustainability without an understanding of evolution. However, and with respect to my second proposition, I will question whether reductionism will assist with the building of this inter-disciplinary commitment because we may well need to think of the passage from beginnings to ends in terms of complex patterns that traditional reductionism finds very difficult to cope with. This may, for example, entail a rethink not of evolution per se, but rather of what drives the evolutionary process (and, by the same token, the quest for sustainability).

ON REDUCTIONISM, AND HORROR

As an African social scientist, I often contemplate a journey that many African social scientists like myself have travelled over the last three decades. We have witnessed the breakdown and eventual collapse of many of the major c.20th social projects that in one way or another were premised on the modernist promise of the "good society". It was this promise that constituted the basis for hope by many who founded these social projects. This included the West European social democracies, the Soviet-style socialist societies, the National Democracies in post-colonial Africa and Asia, and the various revolutionary options such as Cuba, Nicaragua, Mozambique, Algeria and Vietnam. Out of these collapses has arisen a particularly aggressive neo-liberalism with a breathtakingly ambitious c.21st global agenda to bring politics to an end via a complete consensus on the virtues of the market.

Many social scientists have tried to dig deep into the basic structure of social theory to find explanations for both the rise and fall of the c.20th social projects and the Godzillian

spectre of c.21st globalised neo-liberalism. The discovery has been that both in many ways depended on the possibility of certainty derived from an understanding of the basic laws of social progress. For the c.20th social projects, it was Marxian class analysis, or Nationalist anti-colonialism, or the social market of Keynesian economics. But also present throughout the c.20th (with deep roots in the c.19th) was the certainty of the market mechanism inspired by economic liberals like Milton Friedman and Hayek. It is this latter paradigm that is so dominant today, but not unchallenged by any means.

What many social scientists wanted to know is what was it about the epistemology of the social sciences that made it possible for social theory to become the basis not only for the mass mobilization of such great hopes, but also for the perpetration of such great horrors. These horrors apply not only to the obvious things like colonialism, kulakisation, genocide and war, but also to poverty, racism and gender oppression. The origin of this inward search was of course an examination of fascism, starting with the work of the Frankfurt School. Fascism was an unsurprising starting point because it represents the ultimate certainty which stems from a brazenly reductionist social theory. But this just provided the basis for a generalized critique of all reductionism in social theory that gradually came to be applied to all social projects. It is a method in the social sciences that underpins the deep scepticism that exists in many branches of the social sciences of the new neo-liberal certainties articulated most forcefully in Fukuyama's triumphant book entitled the *End of History and the Last Man* (Fukuyama 1992).

The critique of reductionism simply says that if your explanation of a complex social reality depends on the reducibility of these complexities to a few basic factors that are deemed *a priori* to hold greater explanatory weight than any of the other factors, then it also becomes possible to claim to know what is best for the future via the power of prediction. By applying the Newtonian scientific method to the social sciences, it was therefore possible to claim to know the basic laws of motion in society, and therefore also claim to be able to predict the future. This, in turn, made it possible for those with power to legitimize their actions: by claiming to know the objective reality, they were able to justify actions based on the supposed predictive capacity of social theory. When these actions were deemed constructive and good, no one seemed to mind. But when the opposite applied, the ability to resort to objective truth via claims about the use of the scientific method justified the horrors as well. Hence the desire by many post-modern

social theorists to obliterate the possibility of repeating these horrors by obliterating the possibility of the existence of objective truth constructed via the application of Kantian rationality and the Newtonian scientific method. This may be going too far, but the motive is understandable.

For African intellectuals, this journey towards uncertainty was particularly brutal. Decolonisation was celebrated with such great dreams, and the disappointments have not only been bloody and brutal, but the price paid in mass misery and suffering is so awesome many intellectuals have fled the continent in despair. Unsurprisingly, the most passionate and compelling critiques of certainty have emanated from these intellectuals. Whether it is Ben Okri in literature or Achille Mbembe in the social sciences, their fear of certainty is tangible in every word. It's almost as if they were born without a protective skin at all, just raw bloody nerves between them and their experience of reality. For them, there is a direct and short march between reductionism and authoritarianism. Equally, therefore, is their desire to increase the distance between what constitutes knowing and the use of power. Given the increasing centralization of power in contemporary South Africa, this is a desire that has its merits.

Unfortunately, the journey through certainty has not resulted in a new consensus that could become the basis for a new mobilization and new hope. Manuel Castells, the towering contemporary philosopher of the new globalised economy, completes his three volume work on the state of the world by arguing that at best we will enter the c.21st in a state of "informed bewilderment" (Castells 1997). Much of social theory has degenerated either into deconstructionist post-modernism, or a cynical belief in a very crude form of economic liberalism that often shuns the ethical foundations of classical liberalism. This has prompted a reaction, captured most aptly by Raymond Tallis (1997) in his book appropriately entitled *Enemies of Hope*. But what I find most remarkable about contemporary debates in the social sciences is the absence of a reference to what is happening in the natural sciences. Castells, for example, argues that the global economy and society has been reorganized as a grand set of networks but there is not a single reference in his works to the huge body of theory about networks in the natural sciences. This in my view is seriously impoverishing the contemporary search for a way out that avoids hopelessness without returning back to the false promises of certainty. There are profound ethical implications of the notion that the quest for certainty (and, indeed, the

tolerance of poverty) is the greatest threat to democracy. Is there a road between hopelessness and certainty? Answering this question will entail going further than most social theorists have gone because it means going beyond the traditional boundaries of the humanities altogether. For many, this is literally a dangerous no-go zone. And this is where C.P. Snow's ghost comes back to haunt us, albeit in conditions that he never – nor could have - imagined.

REVISITING MODERNITY

The most distinctive feature of the European Scientific Revolution of the 16th and 17th centuries, and of the subsequent c.18th Enlightenment, was the split within what was then generally called philosophy between theories of nature and theories of society. Building on the intellectual and cultural ramifications of the c.15th Renaissance and c.16th Reformation, the Scientific Revolution and the Enlightenment established the foundations for what has generally come to be called the culture of modernity. The culture of modernity was premised on key principles such as a belief in progress, the power of reason, the primacy of the individual, the sanctity of empiricism, the unlimited universalism of scientific knowledge, and the virtues of secularism.

The revolutionary Enlightenment intellectuals were struggling against a universalizing cosmological order that was legitimized and institutionalized by the Church. Starting with Descartes and ending with Habermas today, they needed to assert that the mere act of thinking constituted an act of rebellion and therefore of self-identity – the famous "I think, therefore I am". Out of this emerged Kantian rationality that established the notion that the rational mind was capable of grasping a set of objective realities via the application of certain procedures. This, in turn, paved the way for the mind-body split, with the body associated with nature and the mind isolated as the exclusive means of knowing and doing. It also paved the way for Western intellectual culture to part ways with sophisticated knowledge systems that had evolved in Asia and Africa over at least the previous thousand years that did not depend on the mind/body split.

It was, however, Sir Isaac Newton that stitched together the various elements of the secular scientific understanding of natural phenomena. His basic and most profound claim was that it is possible to understand a complex physical phenomenon by discovering - and then reducing its content to – the phenomenon's quantifiable

component parts. A legitimate explanation, in other words, was one that established the parts, distinguished them apart from one another, and then explained the whole in terms of these identifiable and quantifiable components. From a huge quantity of cases that confirmed the basic method, he was able to finally claim that all physical reality could in the final instance be reducible to three factors, namely gravity, molecules and time. Like the weights, hands and cogs of a clock, all three, for Newton, were constants. And because they were the only constants, everything else was explicable in terms of some manifestation of these three factors.

This grand act of reduction unleashed a phenomenal energy because it made possible a wide range of scientific endeavours that were able to assume that the basic assumptions of the paradigm were valid. In Kuhnian terms, as long as these assumptions remained valid, scientific inquiry could proceed to focus on substance without too much concern about method. The results are well known and need no repeating here other than to say that this made modernity - and its associated revolutions and transformations - possible.

Once the definition of the scientific method had been established in the natural sciences, there was a certain inevitability that social theory would strive to emulate this basic approach. Unsurprisingly this emulation was achieved via metaphor. The classic metaphorical transplant from Newtonian physics to social reality was of course Adam Smith: gravity became the market, molecules became individuals, and the constancy (and reversibility) of time became value. But the same applied to the ideological polar opposite, namely Karl Marx: class struggle (gravity), capital and labour (molecules), and the dialectic (time). And similar reductions for others: Geist through history for Hegel, citizens and the social contract for Locke, bureaucratization for Weber, liberty for the anti-feudal revolutionaries, and so on.

What was common to both the natural and social sciences was the assumption that physical or social reality could be comprehended via the application of the rational mind, and that language was constructed to reflect this reality.

The problem was, however, that Newton's constants did not stay constant. Thanks to quantum physics dating back to Einstein's time (but with earlier antecedents), Newton's basic building blocks turned out to be rather malleable and indeterminate. There was the

famous experiment where two electrons with opposite spins (positive and negative) were taken from the same atom, separated in space, and the spin on one reversed. When the spin on the other automatically and instantaneously reversed itself, scientists were faced with a profound mystery because the possibility of cause and effect mediated by time disappeared. For Einstein, this was a logical impossibility and the explanation would be found in time, he insisted. For others, they came to accept inter-dependency as an inherent property of matter. From this has flowed an extraordinary literature with key terms from this literature becoming increasingly popular, such as non-linear dynamics, chaos, complexity, systems thinking, strange attractors and the butterfly effect. In essence, quantum physics gave to the world an image of reality that was about patterns rather than building blocks, and qualitative explanations of phenomena in terms of the interactions between the component parts rather than linear causal relations between a few primary parts and the rest (determinism). The entry of this literature into the humanities has been largely via management theory because it has been recognized for decades that reductionism is not at all useful when it comes to analyzing the internal dynamics of human organizations. Quantum physics provided the metaphors for an anti-reductionist theory of organizational behaviour. It remains to be debated whether this metaphorical foundation for an entire field of study can continue to be viable. But this is another matter.

The real advances are now being made in the life sciences where the cell itself as the essence of all life is the focus of attention. And herein lies another important difference between today's world and C.P. Snow's world. Many philosophers and historians of science writing today would agree that whereas physics was the premier science of the first half of the c.20th, genetics may well be the lead contender for this status in the second half of that century. As the vanguard of the life sciences and the Ramboesque leader of the biotechnology industry, it is undoubtedly the lead science in the c.21st. But if there ever were 'two cultures' today, then one need go no further than the vast chasm that exists between the physicists and biologists, never mind the social scientists who understand neither of them. C.P. Snow would have loved the promethean modernity of the globalised biotechnology industry, but the belittling of physics would have come as a great surprise indeed.

The living cell holds clues to so many contemporary dilemmas because it sits at a kind of epistemological intersection point. It holds the key to an understanding of evolution, and via biotechnology it may also hold the key to a sustainable future. But how it is conceptualized also has much to add to our current discussion about a viable intellectual basis for cooperation between the sciences and humanities. For a long time after the discovery and elaboration of DNA in the 1950s, molecular biology was caught in a reductionist vice grip. The awesome explanatory power of DNA seemed to obliterate the need to even ask questions that a DNA-centred approach was not geared to answer such as, for example, about the role of enzymes and metabolic regulation. However, this has also begun to change. The renowned Warwick University mathematician Professor Ian Stewart wrote a book with the telling title *Life's Other Secret: The New Mathematics of the Living World*. What then is this 'other secret'? His response to the DNA-centred approach is as follows:

> As a consequence [of this approach], we are in danger of losing sight of an important fact: There is more to life than genes. That is, life operates within the rich texture of the physical universe and its deep laws, patterns, forms, structures, processes, and systems. … Genes nudge the physical universe in specific directions, to choose *this* chemical, *this* pattern, *this* process, rather than that one, but the mathematical laws of physics and chemistry control the growing organism's response to its genetic instructions.
>
> The mathematical control of the growing organism is the *other* secret – the second secret, if you will – of life. Without it, we will never solve the deeper mysteries of the living world – for life is a partnership between genes and mathematics, and we must take proper account of the role of *both* partners (Stewart 1998: x-xi).

For many the notion that a hard square science like mathematics is reconcilable with the soft gooey things that biologists deal with seems bizarre. (My colleague Jannie Hofmeyr at Stellenbosch University's Biochemistry Department tells me that biologists fall asleep when he starts talking in mathematical terms.) However, Stewart is quick to point out:

> If we are going to understand the second secret, we must begin by recognizing that biology is not the only science that has undergone a revolution … Physics and mathematics have also changed beyond recognition, becoming more powerful, more general, more flexible, and *a lot closer to the intricacies of life.* These advances offer radical new opportunities for uniting the biological and mathematical worldviews, at a time when there is a renewed and urgent need for just such a unification (Stewart 1998: xii).

Stewart devotes the rest of his impressive book to a detailed analysis of the operation of the "second secret" via the application of complexity theory and largely succeeds in providing a mathematical description of the physical and chemical context of cellular processes.

It is significant, however, that one of the world's leading scientific initiatives aimed at replacing a DNA-centred with a cell-centred approach is right here in Stellenbosch. Under the leadership of Professor Jannie Hofmeyr in Stellenbosch University's Biochemistry Department, the so-called Triple-J Group for Molecular Cell Physiology is engaged in a project that aims to build an "integrative theory of how the molecular economy in living cells is organized, controlled and regulated". By breaking from DNA-reductionism, this group aims to construct an explanation of cellular behaviour that is deeply rooted in complexity. If they succeed, then as Prof. Steven Oliver of Manchester University argued in a review of their work in the July 4 2002 edition of *Nature*, this "could mean that biologists in the twenty-first century need a rethink of their view of cellular economy that is every bit as radical as that initiated for political economy by John Stuart Mill and William Stanley Jevons in the nineteenth century."

Oliver's use of the term "radical" here is significant because what he is referring to is not a simple shift of focus, but rather a paradigmatic change that will result in seeing the cell as a complex network of living processes that are, by definition, irreducible. The reason why it is becoming increasingly necessary to see the cell as a whole is that as biologists have tried to use genetic knowledge for useful purposes (e.g. disease cures, etc), they are being forced to go beyond gene structure into the lesser known field of gene function.[2]

[2] This insight into the epistemological implications of the commercially driven pressure to move from structure to function comes from Frijof Capra (2002).

As Hofmeyr and his colleagues have found, this is a rich self-organising environment of enzymes, membrane transporters, messenger RNA, ribosomes, metabolites, amino acids, nucleotides and protein synthesis that scientists have often steered clear of attempting to explain simply because reductionist methods were not fit for the task. But without understanding this complexity, genomics may not have a future. Indeed, genomics through practices like genetic engineering may well be unleashing extremely dangerous dynamics on the world if the consequences of human intervention in the cellular world cannot be fully understood because of the persistence of reductionist research methods. This may not bother those who lack an evolutionary perspective or commitment to sustainability, but for those who take evolution – and sustainability – seriously, dangerous genomics should be as worrisome as eugenics. This means, therefore, that a shift from reductionist to complexity perspectives in genomics might well – from a socio-political perspective – be a matter of life and death. This has major implications for the funding of science research.

Professor Keller from MIT has probably written the first comprehensive history of genomic science. In her recent book entitled *The Century of the Gene* she traces out the consequences of the shift from structure to function and how this is resulting in an emerging critique of genetic determinism. Put simply and crudely, traditional genomics has assumed that genetic stability is inherent in the structure of DNA. However, as I have already suggested, it is now increasingly recognized that genetic stability is an emergent property resulting from the complex operating dynamics of the entire cellular network. As Keller argues:

> The stability of the gene structure thus appears not as a starting point but as an end-product – as the result of a highly orchestrated dynamic process requiring the participation of a large number of enzymes organized into complex metabolic networks that regulate and ensure both the stability of the DNA molecule and its fidelity in replication (Keller 2000: 31).

This simple statement contains within it the power to bring down the entire edifice of genetic determinism, including the populist nonsense that the press loves so much. It must force us to question the linear causality between DNA and RNA, RNA and proteins, and proteins and genetic replication, i.e. put crudely the popular image that DNA makes

us what we are. But it is not just popular genetic determinism that is under attack here: if genetic replication is an emergent property embedded in complex systems and regulated by the cell's own epigenetic network, then we may also need to reconsider what drives the evolutionary process. Recent research has revealed that stability is only one part of the story. The other is that mutations can be generated from *within* the cellular structure in response to what Hofmeyr and Westerhoff (2001) call "demands" for a given cell's cellular "products" (e.g. amino acids) by a neighbouring cellular system. If this is true, then evolution is not about occasional random mutation of an inherently stable molecule driven by pure chance followed by natural selection a la the neo-Darwinian view. As biologist James Shapiro puts it:

> These [new] molecular insights lead to new concepts of how genomes are organized and reorganized, opening a range of possibilities for thinking about evolution. Rather than being restricted to contemplating a slow process depending on random (i.e. blind) genetic variation … we are now free to think in realistic molecular ways about rapid genome restructuring guided by biological feedback networks (quoted in Capra 2002: 146).

When this conception of mutation is complemented by other recent explanations of genetic evolution such as gene trading between bacteria and the process of symbiogenesis (which entails the merging of genes from different species), then it must be clear that simplistic (DNA-centred, random mutation) and reductionist explanations of evolution need to be replaced. This must of necessity lead to fundamental questions about how best to manage the shift from a DNA-centred genomics to a systems view that is capable of imagining the entire cell.

In short, like physics in the 1930s, genomic science as the premier science of the early c.21st may also be facing it's moment of truth: either remain wedded to reductionism and blindly pursue the false promises of genetic determinism, or open up to a whole systems approach that not only makes the whole cell the focus of research, but connects this knowledge of the secret to all life to both evolution (as the history of life) and sustainability (as memory of a future for life).

LEARNING FROM COMPLEXITY THEORY

Thus far I have tracked the story of reductionism as it has played itself out in the natural and social sciences. I have suggested along the way that the alternative lies in an appreciation of complexity. I have not, until now, made explicit the theoretical dimensions of complexity thinking. My argument will be that it provides both social science with a way forward that avoids the extremes of hopelessness and certainty, and brings the natural sciences a lot closer to what Ian Stewart so delicately described as "the intricacies of life". But these are not separate movements, they depend on and feed off each other. As social scientists realize that future social transformations will be determined and constrained by sustainability challenges, they need to learn about the dynamics of natural systems (including evolution) from their colleagues in the natural sciences. When they do, they will discover a new language for comprehending social reality that could revitalize their disciplines (as has already begun to happen). Equally, as the impact of unsustainable practices starts to affect the bulk of humanity as negatively as it does the poorest two billion, then the work of the natural scientists becomes the key to the survival of the species. However, the chances of this being done in an ethical way are substantially reduced if this science is not rooted in an appreciation of the deep connections between the human species and the natural system. Only an understanding of evolution can create this appreciation. This is why evolution is so critical for shaping the way we manage ourselves into the future. An understanding of evolution gives humanity its memory of the future. However, much will depend on how we understand evolution from a complexity perspective. (I will come back to this.)

Complexity theory is not a single body of thought that stems from a clearly identifiable central source. Like the process it is best at explaining, it is itself an emergent condition. It is also often confused with chaos theory, but I agree with those who argue that chaos theory and complexity theory may overlap, but at the core they are fundamentally different. Following the internationally renowned work in the field by my colleague Paul Cilliers from the Philosophy Department at Stellenbosch University, I would like for the sake of brevity to simply assert the key elements of complexity theory:

1. Complex systems comprise a large number of diverse elements that in themselves can be simple. Put another way, many seemingly simple elements or transactions can interact in ways that generate an extremely complex system. The whole is, therefore, more than the sum of its parts.

2. The interactions between the elements are non-linear. This means they interact dynamically in richly textured patterns by exchanging energy or information. Even if only some of the elements interact with others, the effects are propagated throughout the system. The results are non-linear because the dimensions of these effects cannot be predicted with certainty.
3. There are many direct and indirect feedback loops operating simultaneously all the time. This makes it impossible to identify a simple linear cause and effect relation. When multiple effects become multiple causes, it becomes impossible to assume *a priori* that any one cause has greater explanatory weight than any other. This is why the specificities of context become so important.
4. Complex systems are open systems. This means they continuously exchange energy or information with other systems located in the external environment. This continuous throughput of energy and information entering the system from external sources means that complex systems operate at conditions that can be described as far from equilibrium. A system in equilibrium is dead because there is no energy or information throughput. It's alive when throughputs are active, and because it is alive it is said to be far from equilibrium yet simultaneously remarkably stable.
5. Complex systems have a memory that is held by the system as a whole. No single element of the system has exclusive control of or access to the memory. It is this distributed memory that makes it possible for complex systems to have a history, which in turn is a critical determinant of the system's future behaviour.
6. The nature and behaviour of the system is determined by the quality of the interactions between the elements, and not by the properties of any one or more of the elements. Because these interactions are dynamic, fed back, rich, and above all, non-linear, the behaviour of the system cannot be predicted by reference to the nature of any of its elements. This is why outcomes that do result from these interactions are referred to as emergent properties and the process of getting to these outcomes as emergence. Although this disallows reductionism and therefore deterministic forms of prediction, causality still exists but in this case as sets of probabilities with actual outcomes dependent entirely on context.

7. Complex systems are inherently adaptive. They can organize and re-organize their internal structures and operations without the intervention of an external agent.[3]

The impact of this core body of theory is already being felt in the diverse fields that have already been mentioned, such as genetics and management science. I have successfully used it to reconceptualise the dynamics of African cities (Swilling, Khan and Simone 2002). Others have used it to rethink the dynamics of the entire global eco-system giving rise to Gaia Theory (see James Lovelock's *Gaia: A New Look at Life on Earth*) or post-corporate developmentalism (see David Korten's *The Post-Corporate World*). In short, it may well already be providing the intellectual basis for cooperation between the sciences and humanities. However, unlike C.P. Snow who called on the 'literary intellectuals' to just understand physics, complexity theory is stimulating an epistemological revolution in both the natural and social sciences. This, in turn, may well be creating the basis for a new intellectual culture rather than just an understanding between different cultures. (Incidentally, the popularization of this culture is already being consciously promoted via the literature of Terry Pratchet and his bestselling Discworld novels, and Ben Okri's fiction – and in particular his non-fiction – reflects a sustained fascination with ungraspable but coherent complex systems.)

Up until this point I have suggested that complexity might form the *intellectual* basis for cooperation between the sciences and humanities. However, cooperation will also need to rest on an ethical foundation. One key advantage of a complexity approach is that there is no basis for deterministic prediction. This is crucial for constructing a culture of humility because all claims to knowing anything must be qualified by the partial and provisional nature of what is known – in short, an appreciation and therefore admission of uncertainty. This, in turn, can help prevent the holders of power from using knowledge to construct false certainties. If certainty cannot be derived entirely and exclusively from rational inquiry, this clears the way for more experiential reflection on the ethical basis for human action in specific contexts when intellectual knowledge is admittedly at best provisional and impartial.

[3] Based on the comprehensive conceptual review by Paul Cilliers (1998).

I would like to take this argument further by suggesting that ethical commitments in future will increasingly be shaped by the challenge of sustainability. This will be the major consequence of the agreements and non-agreements reached at the World Summit on Sustainable Development. However, as I have already suggested, sustainability makes little sense if it is not rooted in an understanding of evolution. An ethics for sustainability, therefore, is equally an ethics rooted in evolution.

EVOLUTION AND SUSTAINABILITY

Many textbook histories of science will place Charles Darwin up there at the start of it all, sitting comfortably on the pedestal with Sir Isaac Newton. Somehow Newton's revolutionary secular image of the universe as a vast mechanical clock was confirmed by the notion that the literal biblical image of creation was a myth. The Newtonian scientific method also seemed confirmed because there were obvious constants that could serve as primary determinants in a grand reductionist theory of the evolution of all species: molecules became species, gravity became natural selection, and time became this grand epochal evolutionary progression from the least to the most evolved species, namely "man".

There was, however, an addition to this basic schema that substantially crudified the Darwinian image of evolution and this has got much to do with the influence of Hobbesian social theory and the tradition of methodological individualism this gave rise to. The addition I am referring to is of course the popular distortion of Darwin's notion of the "survival of the fittest". This was grabbed and used by the new believers in the virtues of the market and racial supremacists to prove that their conception of rabid individualism and selfish competition was perfectly "natural". For social Darwinism, the wealthy capitalist (and the dominant racial group in the racist versions of this approach) was deemed to be the outcome of an inherently natural process. This survives today as a mass cultural belief that capitalism is a perfectly natural form of social organization and in the obstinate persistence of all forms of racism and gender oppression.

In 1894 Thomas Huxley delivered his famous lecture entitled *Evolution and Ethics.* Huxley articulated the classical view that persists to this day that human nature is essentially evil. His argument was that human nature is the product of evolution which he assumed was a natural survival-driven process that conditioned all species to be

inherently selfish, competitive and nasty (i.e. incapable of acting for a greater communal good). In short, there is no morality as we know it in nature. Instead morality and ethics are a human invention constructed by humans (and in particular white Anglo-Saxon Males) to combat natural selfishness for the sake of a wider social good. The result of this line of logic was that ethics has nothing to do with evolution – indeed, ethics arose to save humans (and in particular the West) from their essentially evil natural selves (as represented by the "primitive civilizations" that pre-colonial and colonial travel and conquest was revealing all around the world). Richard Dawkins (1976) with his image of the "selfish gene" is the contemporary spokesperson for this view, albeit stripped of it's distasteful racist history.

From an African perspective, Huxley's views had immensely destructive consequences. They reinforced the already existing presentation of African societies in colonial literature as "still in a state of nature" and therefore lacking the capacity for self-governance based on the kind of ethical systems that were deemed "civilized" from the perspective of the colonizer. This, in turn, justified treating Africans like animals who were like the rest of "nature" equally worthy of torture (to use Bacon's famous phrase) and destroying what were in fact sophisticated ethical systems for effectively managing human affairs and the relations between humans and nature. Like all human systems, they never worked all the time and they could be corrupted, but the point is that they existed and were often completely ignored by the colonizers.

The classical Huxleyian view will collapse if it is possible to demonstrate three things: first, that nature and its evolution over time is not simply about selfish competition but also about creative cooperation at both the microbial and social levels; second, that there is no single "human nature" with a fixed set of properties that can be explained exclusively in terms of genetic evolution but rather a multiplicity of human na*tures* that are the product of genetic and cultural co-evolution; and third, that human morality and ethics in general may well have evolutionary roots in nature which means nature and humans cannot be depicted as inherently separated from one another.

Professor Lynn Margulis from the University of Massachusetts and her colleague Dorion Sagan have forcefully challenged the traditional competitive theory of evolution in their book entitled *Microcosmos: Four Billion Years of Microbial Evolution*. Informed by a

complexity perspective, these biologists have tried to rethink evolution by synthesizing what is known about the living cell in its various microbial forms with what is known about the historic origins of all living species, in particular the hominids and their various predecessors. The result is a detailed empirically justified account of evolution from the perspective of the microbial world where evolution is not the story of a linear progression from the first bacteria four billion years ago to "man" as nature's highest creation, but rather it is the story of an emergent mosaic of all life forms that exist in partnership and inter-dependence with one another – a cosmic conception not dissimilar to representations of universal history that exist in numerous pre-colonial African cosmologies. This new scientific image allows them to argue that:

> …the view of evolution as chronic bloody competition among individuals and species, a popular distortion of Darwin's notion of 'survival of the fittest', dissolves before a new view of continual cooperation, strong interaction, and mutual dependence among life forms. Life did not take over the globe by combat, but by *networking*. Life forms multiplied and complexified by co-opting others, not just killing them (Margulis and Sagan 1997: 29).

Margulis and Sagan argue that this reconceptualisation of the underlying dynamic of evolution is made possible by the three scientific breakthroughs. Firstly, the discovery of DNA and its mode of replication. Secondly, the discovery that natural genetic engineering has been happening for billions of years. Cells can transfer bits and pieces of genetic material from one gene into the other which, in turn, allows the cell to do things that it would not otherwise have been able to do – this being particularly useful when it becomes necessary to respond to new environments. Thirdly, the discovery of mitochondria within the cell which have their own DNA, exist outside the nucleus of the cell, reproduce at different times to the rest of the cell, and enable the cell to use oxygen in ways that would otherwise make it impossible for the cell to live. In short, mitochondria were once separate oxygen breathing bacteria that became part of new cell formations via an evolutionary process that Margulis and Sagan call symbiosis. As they conclude: "Symbiosis, the merging of organisms into new collectives, proves to be a major power of change on Earth" (ibid., p.32).

DNA, recombination and symbiosis make it possible for Margulis and Sagan to apply their conception of cooperative microbial evolution to the evolution of all species up to the present. To this extent they have pioneered a rewriting of evolution that depicts nature as a vast, creative, pulsating and complex network that looks very different to the image of selfish competition that Huxley and the contemporary neo-Darwinists have in mind.

To examine the second assumption in Huxley's worldview, namely that there is a single human nature created by natural evolution, we need to turn to another renowned biologist, namely Stanford University's Professor Paul Ehrlich. Paul Ehrlich's recent book with the telling title *Human Natures: Genes, Cultures and the Human Prospect* sets out to prove two things: firstly, that there is no such thing as a single human nature, but rather a multiplicity of geographically dispersed human natures; and secondly, that there is no evidence that these human natures can be explained exclusively in terms of genetic evolution. His primary target is genetic determinism, and in particular the popular image that genes make us what we are. Like Margulis and Sagan he rewrites the story of evolution, but this time by tracing both the evolution of the natural species and the cultural evolution of the pre-human and human species. His aim is to demonstrate that there is now a multiplicity of different human natures that are a product of genetic and natural "co-evolution" processes that manifested themselves in different ways in different localities and at different times. He demonstrates that there were moments when genetic evolution drove cultural evolution (e.g. in the transition to *homo sapiens sapiens)*, and when cultural evolution has resulted in a fundamental reshaping of the physical environment (e.g. the agricultural revolution after the last ice age). He does not insist that the two proceeded in perfect tandem, but rather traces how they matched and mismatched in time and geographic space. His conclusion, however, is that cultural evolution is lagging now, with negative consequences for the sustainability of human society and the natural system. In his words: "The increasing human ability to *do* things has outstripped the evolution of our ability to *understand* both what we should be doing and the full implications of what we are now doing" (Ehrlich 2002: 281).

Ehrlich has therefore eliminated the notion of a single human nature and softened the division between ourselves and nature by suggesting that some of our social and anti-social cultural traits have evolved from species that preceded us. To this extent he has placed our ethical choices as a species firmly back into the context of evolution conceived

as both a genetic and cultural process. He has also echoed the debate on the same subject in a collection of papers published recently in the *Journal of Consciousness Studies.*[4] In the primary contribution to this collection, Flack and de Waal argue that there is now evidence from observations of primate behaviour that there exists within these primate communities a sense of reciprocity through food sharing, conflict resolution capabilities, and a capacity for empathy, sympathy and consolation. If our primate relatives could choose to be cooperative, how can we possibly assume that cooperative morality is a purely human invention?

Ehrlich concludes by calling for a process of "conscious evolution" that must entail "interdisciplinary scholarship … [so that] those who choose to tackle problems that cross the boundaries of the moment should not be punished, as they often are in academia today. The conservatism that was useful in the past is a luxury that society can no longer afford. Society also can no longer afford the split between the humanities and the sciences (the 'two cultures' of physicist C.P. Snow) or the marginalisation of philosophy" (Ehrlich 2002: 326).

Reconceptualising evolution in a way that returns humans to their evolutionary place brings us back to the challenge of sustainability. As Margulis and Sagan argue, "we can rescue for ourselves some of our old evolutionary grandeur when we recognize our species not as lords but as partners: we are in mute, incontrovertible partnership with the photosynthetic organisms that feed us, the gas producers that provide oxygen, and the heterotrophic bacteria and fungi that remove and convert our waste. No political will or technological advance can dissolve that partnership" (Margulis and Sagan 1997: 16). We have been, and always will be (if we survive), embedded in these natural systems. But we are also slowly destroying these life support systems through human actions that cause ecological disasters such as climate change, desertification, soil degradation, deforestation, biodiversity destruction and the misuse of scarce water resources.

We are, in short, extracting natural capital at a rate that is greater than the capacity of natural systems to regenerate these resources, and we are dumping waste into natural systems at a rate that is greater than what these systems can withstand. The blind persistence of both these trends is already breaking down the evolutionary partnership

[4] See *Journal of Consciousness Studies*, 7, 1-2, 2000.

that Margulis and Sagan describe at a cost that is at this stage carried by the world's poor (who lack basic access to water and energy), but also increasingly by the rich (who suffer the health dysfunctions of a poisoned environment and gluttonous diet). However, Erhlich is right: a genetically determined response to this crisis might be too slow in coming, and so it is up to the humanities to rethink the way contemporary societies are organized so that they can be weaned off their dependence on life destroying support systems. If this fails to happen, the richer countries (and richer groups in poorer countries) will use greater and greater force to gain more secure control of diminishing natural resources (hence US military action in the Middle East), and the suffering of the poor will inevitably get worse than it already is which, in turn, will further destabilize global social and political systems. It therefore follows that a sustainable society is both more equitable in social terms and less dependent on the destructive use of natural resources.

If social scientists are to find a middle way between hopelessness and certainty, they will need to rethink the primary foundations of social theory in light of knowledge from the scientists about the natural limits to traditional conceptions of development. This is what I mean by a sustainability perspective. In the words of a paper by Wolfgang Sachs and an eminent group of analysts issued before the World Summit on Sustainable Development:

> Without ecology there will be no equity in the world. Otherwise, the biosphere will be thrown into turbulence. The insight that the globally available environmental space is finite, albeit within flexible boundaries, has added a new dimension to justice. The quest for greater justice has, from time immemorial, required us to contain the use of power in society, but now it also requires us to contain the use of nature. The powerful have to yield both political and environmental space to the powerless, if justice is to have a chance.[5]

In order to live up to this challenge, social theory will need to jettison what has already been largely jettisoned in the natural sciences, namely the tendency towards reductionism. If social scientists are to successfully rethink – and re-imagine – society from an evolutionary and sustainability perspective, they would be well advised to experiment with the language of complexity theory. This theoretical framework holds

[5] See www.joburgmemo.org, 15 September 2002.

promise because it invites us to look for patterns rather than parts, probabilities rather than predictions, processes rather than structures, and non-linear dynamics instead of deterministic causalities. To this extent it makes possible an epistemology that treasures uncertainty and therefore reinforces a sense of humility (because less can be claimed to be known about the whole even though more can be comprehended), and it creates for this reason a greater space for ethical justifications of human action.

If I had more space, I would have linked this last point to the burgeoning new literature on consciousness taking place amongst a group of neuroscientists, psychologists, biologists and cosmologists. Once again informed by complexity theory, new insights into consciousness and mind are being generated that create new bridges between the physical, social and spiritual worlds. These insights stem from a concerted effort to "re-embody the mind" and in so doing turn Kantian rationality on its head. This, in turn, makes possible direct and exciting linkages into the vast and neglected knowledge systems that have traditionally been excluded from so-called Western Thought. It also makes possible bridges between secular and non-secular knowledge systems that have until recently been difficult to talk about in mainstream academic circles.

CONCLUSION

If we wanted to identify a c.21st equivalent of C.P. Snow, Professor Paul Erhlich would be an ideal candidate. Like Snow, he came from the sciences and called for a dialogue between the sciences and humanities in order to be better prepared for the future. And like Snow, the immediate consequence of his call is to get the humanities to wake up and do something. But the differences could not be greater. Whereas Snow wanted the humanities to recognize the virtues of the unbound Prometheus of global modernization driven by science, Erhlich is horrified by the consequences of allowing this Prometheus to remain unbound. (Snow too would have been horrified by a world that is now more unequal than it was in 1959.) For Erhlich (and many others), the unbound Prometheus has become a threat to the sustainability of the environment and therefore the survival of the human species. Ehrlich challenges the humanities to rebound Prometheus via a process of 'conscious evolution' inspired by the possibility of sustainability.

I have suggested that if there is an intellectual basis for cooperation between the sciences and humanities in the c.21st, then it would be a shared understanding of evolution coupled

to an ethical commitment to sustainability underpinned by a complexity theory perspective. (I would have liked to add to this the notion of the 'embodied mind', but this will have to be left for another discussion.)

Before concluding, three warnings are required. Firstly, I would like to warn against the simplistic transfer of metaphors from the natural to the social sciences. This has already happened in management science. The result is ideological claptrap that looks like science because it uses the language of science. While accepting that the use of metaphor is unavoidable because this is the essence of language, we have a duty to explain our terms before we use them. In particular, we must respect the historic origins and context of the discourse we use. Secondly, although I have consciously targeted reductionism for the sake of the argument, there is a danger that this leads to a dualistic fallacy with reductionism and complexity counter-posed to one another. Reductionism and complexity are in reality on a continuum, and there is certainly a place for reductionist analyses under certain circumstances. Where one is on this continuum depends on the context and the strategic purpose of a particular analysis. The only requirement is to be explicit about this location and the rationale for the strategic purpose. Thirdly, I am sceptical about the usefulness of recent attempts to build an integrated theory of all natural and social life (for example, Capra 2002). Although this is not a problematic academic objective in and of itself, I am fearful that once this is called a Theory, it runs the danger of becoming codified into a new grand narrative that can easily be captured, simplified and then misused.

I would like to conclude with a quote from Vandana Shiva, the tireless Indian academic and activist who wrote an article shortly before the Summit called *Paradigm Shift*.

> How do we turn from the ruins of the culture of death and destruction, to the culture that sustains and celebrates life? We can do it by breaking free of the mental prison of separation and exclusion and see the world in its interconnectedness and non-separability, allowing new alternatives to emerge. … We need once more to feel at home on this earth and with each other. We need a new paradigm that allows us to move from the pervasive culture of violence, to a culture of non-violence, creativity, and peace… (Shiva 2002: 32-34).

The movement of conscious evolution has begun.

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