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David Grierson

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The Shift from a Mechanistic to an Ecological Paradigm

David Grierson, University of Strathclyde, Scotland, UK

Abstract: Following Kuhn (1962) paradigm shifts are described as discontinuous revolutionary breaks with earlier thoughts and experience. The mechanistic paradigm sees nature as a machine composed of related but discrete components. It helps support the idea that we humans are the crown of creation, the source of all value, the measure of all things. The ecological paradigm offers resistance to the mechanistic way of thinking and a rejection of the assumption of human self-importance in the larger scheme of things. Emphasis is placed on the whole and the view is described as holistic, organic, ecological or systemic. Physicist Fritjof Capra argues that society is embarking on a fundamental paradigm shift towards an ecological view of the world as an integrated network of all living and non-living entities (Capra, 1986). The paper identifies roots of both a mechanistic (or reductionist) and an ecological (or holistic) paradigm and describes significant aspects of a shift from one world view to the other, along with the importance of changing knowledge and values in contemporary and historical sustainability practices.

Keywords: Paradigm Shift, Mechanistic, Ecological

Challenging Growth

SCIENCE AND TECHNOLOGY have without question driven our evolutionary progress, and helped shape our cities. They have been largely beneficial to our societies and cultures. What is offered in this paper though is a particular perspective which recognises that such progress has been achieved at significant cost. Lewis Mumford in *Technics and Civilization* (1934) wrote about the progress of technology and its relationship to society and particularly its role in the development of cities and culture. He advocated a new culture in which, rather than simply shaping our lives, technology would enhance the environment by enabling us to achieve a better quality of life. As a holistic philosopher, Mumford was arguably prefiguring a shift in our collective world view that Thomas Kuhn (1962) would help articulate in the philosophy of science three decades later. The *mechanistic* (or *reductionist*) *paradigm* has dominated our culture for several hundreds of years, having shaped Western society and significantly influenced the rest of the world. Some have argued that many of our current environmental problems arise from seeing ourselves as separate from nature. The roots of this perspective lie in the Scientific Revolution, which dates from the time of the Copernicus, Kepler, Newton and Galileo. The modern physicist Fritjof Capra argues that the major problems of our time require a radical shift in our perceptions, our thinking and our values. He believes that society is embarking on a fundamental paradigm shift 'as radical as the Copernican Revolution'. He has helped define a new perspective, which sees the world as an integrated network of all living and non-living entities. Just like the medieval cosmology of the Great Chain of Being, actions in any one part this network affect the whole.

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The new paradigm, as suggested by Capra, sees different groups working on a variety of causes (ecology, feminism, community politics, architecture, urban planning, consciousness raising etc.) with common elements, which are eventually brought together in collective action. The enormous changes brought about by the mechanistic paradigm have impacted on all aspects of life, bringing many positive benefits. However our needs have significantly changed in recent times. Previously entrenched ideas and values are now being brought into question (e.g. nature exists to serve humanity). Assumptions are being challenged. Some, like Capra, believe the mechanistic approach is now giving way to an ecological one.

A number of theoretical/conceptual positions are introduced here which to varying degrees augment the ecological view. The Gaia hypothesis, for example, sees the earth as a self-regulating system within which conditions suitable for life are maintained by feedback processes involving both living things and the non-living part of the planet. In economic theory Richard Douthwaite in *The Growth Illusion* (1992) asked how we could have progressed along the path of economic growth, technical innovation and increasing efficiency for so long and yet end up with massive unemployment, wide spread poverty and the fear of economic and ecological collapse. His answer was that "economic growth has enriched the few, impoverished the many, and endangered the planet". He argued that as economic growth continues it takes more and more resources to achieve additional increments of growth. The whole process, in effect, becomes progressively more inefficient. The *Limits to Growth* theory (Meadows et al, 1972) applies thermodynamic laws to economics, after economist Georgescu-Roegen. These imply that all production that uses material and energy eventually transforms them into a more random, chaotic, or disordered, state. A contemporary exponent of this perspective, Herman Daly advocates that there is a limit to the use we can make of scarce resources. Waste, he says, is an inevitable by-product of the extraction and use of resources. Economic growth in the conventional sense is more of a problem than a solution because it damages the environment and leads to social injustice. But the idea that we need to abandon the constant craving for material wealth and redefine our notion of growth is an anathema to many. Modern environmentalists nevertheless argue for the necessity of an ecological society based on a comprehensive set of sustainable policy objectives that cover all aspects of our lives; economic, social, cultural, political, technological and environmental. Such a society will be constructed on the basis that there are ecological limits to material growth.

This paper identifies key components and characteristics of the mechanistic and ecological paradigms and traces historical and contemporary examples of a philosophical shift.

Shifting Paradigms

'Changes from one kind of civilisation to another do not happen often in history: the invention of agriculture, the rise and fall of conquest states…and the coming of industrialism. An earlier generation may have been justified in discounting any further such radical changes. We cannot. Most trends of the past are simply not sustainable…' (Goerner, 1999)

The dramatic changes of thinking that took place in the field of atomic and subatomic physics at the beginning of the twentieth century led Kuhn, in 1962, to define the idea of a scientific *paradigm.* He described it as 'a constellation of achievements – concepts, values, techniques, etc. – shared by a scientific community and used by that community to define legitimate problems and solutions' (Kuhn, 1962). Kuhn argued that a paradigm gains its status because it is more successful than a competitor at solving some problems that have been recognised as acute, and that changes of paradigms occur in discontinuous, revolutionary breaks, which he called *paradigm shifts*. The nature of these shifts is such that it is not always possible to accurately trace the rise and fall of new ideas as their beginnings may be barely perceptible and they might end unnoticed. Kuhn also displays a sense in which paradigms not only belong to a scientific community but are constitutive of society and nature as well. Although some question Kuhn's analysis, suggesting that the shift from classical to quantum theories in the twentieth century failed to display all the characteristics he suggests, the idea of paradigms that he puts forward is a useful one for articulating how change may occur.

The Mechanistic Paradigm

bThe underlying causes of the modern environmental crisis lie in the revolutions of science, religion and economics in the early modern age, which helped to lay down the foundations of the dominant Western worldview, and shaped the institutions such as the systems of capitalism and state socialism. From the middle of the sixteenth century to the end of the seventeenth, early 'modernism' and the principles of 'classical' science established ways of thinking about the world and our position in it, which were vastly different from the medieval cosmologies and pre-modern notions that preceded them. Although this is now refuted, classical science held that nature is a machine whose parts are related but discrete. Its fundamental particles, like atoms, electrons, and quarks are solid bodies in empty space. We, as observers of nature (subjects) were separate from it (the object) so we can be 'objective', impersonal, or detached, about it. The widespread acceptance of this view meant that the idea that humans were the crown of creation, the source of all value, the measure of all things, became deeply embedded in our culture and consciousness.

The 'mechanistic' (or 'reductionist') paradigm dominated our culture for several hundreds of years, shaped Western society and significantly influenced the rest of the world. Capra argues that it is now receding because, as a model, it has a number of entrenched ideas and values that have recently been brought into question, namely:

- the view of the Universe as a mechanical system composed of elementary building blocks;
- the view of the human body as a machine;
- the view of life in society as a competitive struggle for existence;
- the belief in unlimited material progress to be achieved through economic and technological growth;
- the belief that a society in which the female is subsumed under the male follows a basic law of nature.

Many of our current environmental problems arise out of seeing ourselves as separate from nature. This is an approach often attributed to the seventeenth century ideas of Rene Descartes (1596 – 1650), who saw science as rendering us the "masters and possessors of nature", and in particular, Francis Bacon (1561 – 1626), who saw it as 'enlarging the bounds of Human Empire'. The roots of this perspective lie in the Scientific Revolution, which dates from the time of the astronomer Nicolaus Copernicus (1473-1543) to that of physicist Isaac Newton (1642-1727), and coincides with the beginnings of industrial capitalism. The kind of science associated with this period is characterised as being primarily concerned with achieving material progress and was imbued with values identified with liberalism and the French Revolution. It is often referred to as 'classical' science, in order to distinguish it from the newer scientific outlook within twentieth century physics, expounded by people like Henri Bergson and Alfred North Whitehead, where Greens identify a reaction against many of the beliefs and assumptions of modernism. But even although the scientific discipline has moved on here there is less evidence of significant socio-political and cultural change.

From ancient pre-scientific revolution times and prevailing in some non-western cultures up to the present, the main goal of science has been gaining wisdom and understanding while remaining in harmony with nature. However in the western world, since Bacon, the goal of science has tended to be patriarchal and has largely involved the pursuit of knowledge in order to control and exploit nature. Dualism, as between mind and matter - championed by the acknowledged father of modern philosophy, Rene Descartes - sets the paradigm for understanding most of Western culture. Descartes doubted everything until he reached a definite conclusion in his famous dictum 'Cogito ergo sum'. He deduced from this that since thought was the essence of nature, mind and matter were separate and distinct entities. Descartes saw the material world as a machine without life or spirit. The natural world functioned in accordance with mechanical laws and nature could be explained in terms of the mechanistic movement of the parts. Even human beings belonged to a category of machine in which the human body was seen as a container activated by a soul that was connected to the body via the pineal gland in the brain. Thanks to Cartesian dualism the mechanical view of nature became the dominant view of classical science. Isaac Newton used differential calculus to come up with a mathematical formulation that undertook Descartes' work and completed the mechanical world view. For Newton, God had set the whole Universe in motion and it has continued to run ever since like a machine governed by immutable laws. Such a view is essentially deterministic and fatalistic. It says that given sufficient knowledge of nature's laws we could have predicted the present. The future is already cast, and free will is an illusion.

Towards the Ecological Paradigm

In *A Green History of the World* Clive Ponting relates many examples where human societies have failed to achieve a sustainable balance between their own material demands and the environment's well-being. He describes the Sumerian empire as the first literate society on Earth to succumb to self-inflicted ecological collapse. The technical innovation of irrigation, which had been invented around 5500 B.C., eventually brought Sumeria to its nemesis. Irrigation increased crop yields substantially but it also increased the salt content and water retention of the soil. The rapid population growth, which resulted from increased crop production, meant that the land could not be left to lie fallow in order to recover. Crop yields remained high for a time, but collapsed abruptly in 2400 B.C. The food shortfall made it difficult for the empire to support its army and Sumeria was conquered within a matter of decades.

The rise and fall of Sumeria illustrates a tendency that has shown itself time and again in the history of human society: a given technological development increases humanity's ability to extract a higher level of comfort from the natural world, but it does so at the cost of greater environmental damage. Ponting points out that damage to the environment was usually one among a number of factors, which caused these societies to come apart, and in such cases 'the decline and eventual collapse were usually prolonged…and generations living through this process would probably not have been aware that their society was facing long-term decline' (Ponting, 1991).

Modern science pioneered by people like Copernicus, Kepler, Newton, and Galileo asserted that the world operated according to consistent physical laws which could be discovered through reason and experiment and applied to practical effect. To a rising class of capitalists that followed, better knowledge has resulted in better machines, which have lowered production costs, attracting more and more people into the system and accumulating the capital needed to develop better production methods and machinery. By the late eighteenth century the pursuit of technological advantage in Britain had culminated in the industrial steam engine, a machine which would power the Industrial Revolution through the next hundred years. During the nineteenth century better technology raised the standard of human welfare across Europe but inflicted greater environmental damage as forests were systematically destroyed. Eventually, because wood was becoming too scarce, it was replaced by coal as the primary source of fuel. For centuries humans had limited the burning of coal, because as a fuel source it was inefficient, messy and difficult to extract from the ground. Dwindling wood stocks and technological breakthroughs in the 1840s enabled coal to be converted into heat much more efficiently and the industry grew rapidly. But the environmental trade-off for coal was worse than it was for the steam engine. As 'progress' became the key word of nineteenth century philosophy and politics, massive increases in production and efficiency were accompanied by blackened skies, putrid rivers, and other side effects leading to William Blake's passionate assault on the 'dark Satanic Mills' of industrial England.

Resistance to the mechanistic way of thinking and a rejection of the assumption of human self-importance in the larger scheme of things has a long history. This kind of thinking can be traced back through the work of Saint Francis of Assisi, Henri David Thoreau, John Muir and Aldo Leopold, and within medieval and Renaissance cosmologies, with their images of the world that were holistic, organic, ecological, and spiritual. The medieval *organic metaphor* of nature also derived from a human experience in which the Earth was perceived as a living body. So the circulation of water through the rivers and seas was comparable to the circulation of blood; the circulation of air through wind was the breath of the planet; volcanoes and geysers were seen as corresponding to the Earth's digestive system. There were a number of Renaissance organic philosophies based on *vitalism* – the idea that all parts of the cosmos were unified in mutual interdependence, in which everything was saturated with life, and it was impossible to distinguish between living and non-living things. Earth was a living being among humans. Even although she could also be unpredictable, wild, passionate, and dangerous, *Mother Earth* nourished and nurtured us and so should command respect and reverence. The organic view and the medieval cosmology stemmed from the Great Chain of Being, which had originated with the Greeks and had been transmitted to medieval writers who adapted it to their own cosmology.

The Great Chain is a designed hierarchy in nature in which all matter, from rocks to angels, is in possession of a soul, and all earthly species of organic life have their appointed place on the chain, from the insects above the rock to the humans below the angels. All were joined together in a fixed hierarchy, and were interdependent. The metaphor and related ideas, which continued to influence essential assumptions framing scientific theories into the eighteenth century, placed people and nature in a mutual relationship in which each link in the chain was vital for the continued existence of the whole chain. The elimination of one link would dissolve the whole cosmic order and render the world muddled and disjointed. The idea of a coherent cosmic order based on continuity and gradation was tied to the notion of *plenitude*, or abundance, which held that the world is filled by diverse living things, such that all species that could *theoretically* exist do in fact exist. Fullness stemmed from a hypothetically infinite process of reproduction. The diversity of living organisms was deemed to be so great and the numbers so abundant that some feared that a single species could multiply indefinitely and eventually cover the entire earth. This view led Malthus (1778) to posit that humans could theoretically fill not only earth but all planets in our solar system if population growth was not held in check by wars, famines, disease, and poverty, and by competition between and within species. The idea of there being physical constraints to growth of various types is the basis of classical economics.

bGreens today advocate a 'sustainable society', not simply because they think it would be a better place to live, but because they believe it is scientifically legitimate to do so. The modern ecological view of science borrows from a number of writers in the first half of the twentieth century, including Alfred North Whitehead, Henri Bergson, and Lewis Mumford. It draws on the work of Michael Faraday (particularly in the sense that his *electromagnetic field* refuted the Newtonian idea that all entities were separate and governed by fundamental mechanical laws determined by God), Albert Einstein (whose *relativity theory* offered an interconnected view of the Universe), *evolutionary theory* in biology, and in *quantum theory* within subatomic physics. More recently the *Gaia hypothesis*, has offered ecologism its own scientific paradigm. *Gaia* refers to the Earth as a self-regulating organic system, which is striving toward a steady-state condition favourable for the maintenance of life, while being capable of responding to changing needs for human sustenance.

The Gaia hypothesis, posited by former NASA scientist James Lovelock (1979), relates aspects of the Greek and medieval cosmologies, the organic metaphor, and new physics. Lovelock's concept sees the earth as a self-regulating system which is impacted upon by humans but cannot be controlled by them and in which conditions suitable for life are maintained by feedback processes involving both living things and the non-living part of the planet.

According to the hypothesis, the self-regulating organic system is striving toward a steady-state condition that is favourable for the maintenance of life, while being capable of responding to changing needs for human sustenance. In seeking homeostasis this complex system can adjust, within certain limits, to large-scale human technological interventions. But the current pattern of urbanisation, resulting as it does in energy-intensive, highly-pollutant, forms of human settlement represents interventions which are spiralling out of control, causing levels of environmental degradation and social disruptions that threaten the earth's equilibrium. Traditional strategies of policy reform geared to technological solutions are less and less capable of correcting the imbalances that are being created as the global urban population rapidly increases.

From a Mechanistic to an Ecological Paradigm

Physicist Fritjof Capra describes how the major problems of our times require a radical shift in our perceptions, our thinking and our values. In his analysis of cultural transformations Capra generalises Kuhn's definition of a scientific paradigm to that of a social paradigm. He defines this as, 'a constellation of concepts, values, perceptions, and practices shared by a community, which forms a particular vision of reality that is the basis of the way the community organises itself' (Capra, 1982).

There is now irrefutable scientific evidence that we are harming the biosphere and human life in alarming ways that may soon become irreversible. In recent years advances in satellite technology have also provided us with environmental data that gives us crucial insights into changing geological patterns, global warming and the depletion of the ozone layer. What they point to is an environmental catastrophe on an unprecedented scale. We are now confronted with a whole series of global environmental problems; relating to the rapid depletion of natural resources, energy and materials, atmospheric pollution, climate change, deforestation , and dramatic loss of biodiversity. The more we look into these problems the more we come to realise that they are interconnected and interdependent, in other words *systemic problems*. For example stabilising the world population will only become possible when poverty is reduced throughout the world. The extinction of animal and plant species on a massive scale will go on as long as the developing world is burdened by huge debts. Scarcities of resources and environmental degradation combine with rapidly expanding populations to lead to the breakdown of communities, collapsing infrastructures in cities and to ethnic and tribal violence. Ecologists now describe these problems as different facets of a single crisis deriving from an outdated worldview that is no longer adequate for dealing with our overpopulated, globally connected world. Many now advocate that the dominant set of attitudes towards nature and environmental issues in Western society that underpins this view needs to change. There have been those, like Lewis Mumford, who foresaw the need for change earlier in the twentieth century:

> "An age of expansion is giving place to an age of equilibrium. The achievement of this equilibrium is the task of the next few centuries…The theme for the new period will be neither arms and the man: nor machines and the man: its theme will be the resurgence of life, the displacement of the mechanical by the organic, and the re-establishment of the person as the ultimate term of all human effort. Cultivation, humanization, co-operation, symbiosis: these are the watchwords of the new world-enveloping culture. Every department of life will record this change: it will affect the task of education and the procedures of science no less than the organization of industrial enterprises, the planning of cities, the development of regions, the interchange of world resources" (Mumford, 1944).

Throughout the twentieth century the shift from the mechanistic to the ecological paradigm took a variety of forms and moved at different speeds in disparate scientific fields. It has involved scientific revolutions, reactions and complex oscillations but primarily the basic tension has been between the parts and the whole. To emphasise the parts has been called *mechanistic*, *reductionist* or *atomistic*; while emphasis on the whole is described as *holistic*, *ecological* or *systemic.*

In dealing with environmental and social problems, the modern deterministic and mechanical view of the world promotes a specialised instrumental approach, which relies heavily on scientific method and technological know-how. When this is associated with the relentless pursuit of material progress, based on a no-limits-to-growth mentality, we loose sight of ecological limits and the fact that beyond a certain threshold (carrying capacity) such a social system depletes the world's natural resources and overburdens the biosphere with waste products that are incapable of being absorbed by Gaia's self-balancing system. In this way we undermine the earth's equilibrium-seeking mechanisms.

Faced with ecological overreach and collapse, the response has generally been limited to a strategy of policy reform geared to the technological solution - emphasising technological means for solving problems which are essentially social, political, economic, and ultimately cultural.

In *The Tragedy of the Commons* (1968), Garret Hardin refutes the implicit and almost universal assumption that all of our modern problems (rapid population growth, pollution, nuclear war) have a technical solution. He defines a 'technological solution' as one that requires 'a change only in the techniques of the natural sciences, demanding little or nothing in the way of change in human values or ideas or morality' (Hardin, 1968). Barry Commoner (1971) proposes a functional connection between pollution and economy via modern technology. He sees the link emerging in two ways. Firstly he argues that pollution tends to become intensified by the displacement of 'older productive techniques by new, ecologically faulty, but more profitable technologies' so that pollution is an unintended by-product of the drive to increase profit by introducing technologies that increase productivity. Secondly the cost of environmental degradation is borne, not by the producer, but by society as a whole. Polluters are therefore being subsidised by society. Commoner (1971) argues that these relationships must change. If technological solutions to the problems of growth are impossible, then it follows that more profound social changes, in our thinking and in social practice - in human values or ideas or morality - will need to be argued for. According to Hardin such changes will require the recognition of the necessity of 'mutual coercion' in social arrangements (e.g. pollution taxes) and a careful rethinking of the meaning of 'freedom'. He offers the legislation against robbery as an example of human beings becoming more, not less, free through mutually agreed laws. Quoting Hegel Hardin suggests that "Freedom is the recognition of necessity".

In *Gray World, Green Heart* (1994) Robert Thayer suggests that in the midst of an ecological crisis characterised by a deteriorating technological world we have latched on the increasingly popular notion of sustainability that raises questions about our technologies, our landscapes and ourselves. He is convinced that the notion of sustainability has been thrust of the forefront of our thinking and our policy debates because it promises to respond to the challenges posed by technology and nature. The urgency of the conflict means that the movement toward sustainability, he argues, is both inevitable and essential. Sustainable planning, design and development may become the major means of easing the growing tension that exists between those who believe that technology can resolve all of our problems and those who know that it cannot. Through careful normative evaluation we can develop those technologies that can be proven to be sustainable, and employ these productively at a reduced cost to the ecosystem, within our resource availability, while maintaining our cultural integrity. To achieve this we need conduct as many experiments and look to as many alternatives as possible. In theory at least the global community has the means to achieving sustainability. It is conceivable that with sufficient investment in basic needs and infrastructure, communities in the developing world can provide the food, water, farmlands and labour-intensive industry needed to raise them above absolute poverty. This should result in more decent living standards and bring about stable levels of population among the billions who will be born there in the next few decades. But neither those who write-off science as a possible contributor to human well-being and environmental stability nor those who believe that the 'holy grail' of technology will solve all of our human ills and rid us of all our environmental problems, can ever be more than half right. Technology is both the cause and the cure of what ails us. Human strategy and planning is what gives technology its stimulus and defines its limits. The modern world, with its rapid growth in population, its pursuit of material wealth via increasing rates of resource consumption, and its rapid shift from rural to urban life via the process of urbanisation, lacks the strategies of conservation in the broadest and yet most important sense. Technological solutions, no matter how clever, cannot facilitate infinite growth in a finite system. Our technological gadgetry has, thus far, merely shifted the problem around often at the expense of more energy and materials use and therefore more pollution.

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About the Author

Dr. David Grierson

Dr. Grierson is both an architect and academic. He currently directs the Postgraduate Programme in Sustainable Engineering, at Strathclyde University and is a Director of the David Livingstone Centre for Sustainability. His teaching and research interests are in sustainable architecture and urban design. He is particularly active in the integration of teaching and learning activity across the postgraduate community, and the promotion of knowledge exchange and CPD through increased engagement with business, industry, the professions, and other institutions. Dr Grierson is a Fellow of the Higher Education Academy (FHEA) and a visiting lecturer in sustainability at Manchester Metropolitan University, the University of Rome, and the University of Florence. His own architectural work has been exhibited at the Royal Academy Exhibition in London and he has gained a number of architectural awards including two Glasgow Institute of Architecture (GIA) Design Awards and a Sir Rowan Anderson Silver Medal for Architectural Design (RIAS). He has an active role in both the architectural and engineering professions, being listed on the UK Register of Architects (ARB), acting as the Royal Academy of Engineering Visiting Professor (Engineering Design for Sustainable Development) contact for Faculty, and representing the University as a member of the Glasgow Urban Design Panel which advises Glasgow City Council's Planning Committee on planning decisions.

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