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'Learning to live with an angry planet: human relations with the earth in the past and future'

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Overview:
The earth is a dynamic and changing system. Scientific study of its past shows considerable shifts in physical systems, temperature, ice and sea cover, and more. Past human civilisations have been affected considerably by such changes. These days there is strong evidence that the earth is warming and that this being accelerated by human activity. Effective approaches to this scale of challenge are likely to require significant changes in how humans live and how we relate to the earth and each other. If existing trends in physical systems continue, effective co-operation and governance beyond the existing restrictions of national boundaries will also be required.

Key ideas:
Climate change: the variation in the earth's global or regional weather over time. It involves changes in the variability or average state of the atmosphere over periods ranging from decades to millions of years. These changes can be caused by dynamic, natural forces and, more recently, by human activities.

Earth's (physical) systems: five major related dynamic processes: the **biosphere**, largely related to terrestrial cycles; the **cryosphere**, largely related to the behaviour of ice sheets and glaciers; **continental**, largely focused on the relationship of the earth's surface to changes in other aspects of the system; **oceans**, and how they change over time and circumstance; and **atmosphere**, the 100km gaseous band which acts as the earth's thermostat and also contains the troposphere, a turbulent 10km band close to the earth which helps to make weather.

Greenhouse effect: used to describe the process by which the earth radiates the sun's heat back into the atmosphere. Global warming is believed to be caused by increasing concentrations of greenhouse gases such as carbon dioxide and methane in the lower atmosphere which prevent heat from escaping.

Carrying capacity: the supportable population of a system (in this case the earth). Below carrying capacity, populations tend to increase; above, they tend to decrease.

During the lecture, Professor Boulton made reference to the significance of some key scientists and groups. These were:

- **Copernicus** (1473–1543) – Polish astronomer and mathematician who first postulated that the earth orbited the sun and not vice versa.
- **James Hutton** (1726–1797) – Scottish farmer who trained as a lawyer and medical doctor, often called the father of geology. He postulated that the physical appearance of the earth was the result of a long history of natural processes.

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- **Charles Darwin** (1809-1882) – English naturalist who proved that all life on earth has evolved over time through a process of natural selection against a background of varied and changing conditions.
- **Thomas Malthus** (1766-1834) – English clergyman, demographer and political economist who predicted a steep rise in population after the industrial revolution which resources would ultimately not be able to sustain.
- **The Club of Rome** – founded in 1968 and changed considerably in 1970, this small group of thinkers attracted attention and controversy with the publication of 'The Limits to Growth' in 1972. It suggested that the earth's key resources and systems could not sustain themselves in the face of increasing human demand, with some key resources being depleted by 2000. It was updated twice in 1993 and again in 2004.
- **International Panel on Climate Change** (IPCC) – a scientific body established in 1988 by the World Meteorological Organisation and the United Nations Environment Programme. A key function of the IPCC is to publish special reports to assist with the implementation of the UN Framework Convention on Climate Change (leading to the Kyoto protocol).

Summary:

Professor Boulton prefaced his lecture with a number of salutary observations:

- Key scientific discoveries such as those of Copernicus, Hutton and Darwin remind us that human beings are neither the centre nor the pinnacle of creation, but the chance outcome of a difficult and complex history.
- The earth, over its 4.5 billion year history, could be likened to an angry beast – the last thing humans should do is poke it with a stick!
- Every human society which we know about has a narrative and perspective on its relation with the earth and nature which profoundly conditions how that society lives. In the "west" and Western Europe, this perspective comes largely through science.
- It used to be thought that the human drama was being played out against an unchanging environmental background, that the earth was a static system, and that the only outcome of using its resources was human material benefit. It is now known that these resources are finite and the consequences of their exploitation are complex.
- At the same time, while it is recognised that the earth's past is replete with extreme shifts in physical systems there has been an assumption that these events belong to the past and the earth is now somehow unimaginably different. These presumptions may be wrong. Extreme events have happened before and they can happen again.

Professor Boulton began the substantive part of his lecture by asking two questions:

1. How does the Earth work when left to itself?
2. How do humans affect this?

He explored answers to these questions through an examination of some of the earth's physical systems, beginning with evidence from the oceans. Using data derived from analysis of the chemical composition of sediment cores from the North Atlantic basin, he showed that there are regular swings in the salinity of the ocean. Salinity is high when the earth is less warm and low when it is warmer. These swings in salinity need a water volume of 50million km^3 to be extracted and introduced to the sea. This is the approximate volume of the polar ice sheets, suggesting these are the source. These

swings in salinity are an indicator of 100,000 year cycles of cooling and warming over the last 700,000 years. Before then the cycles lasted approximately 40,000 years.
Professor Boulton then showed a slide sequence [slide numbers 7-27 in the accompanying set] of ice cover over the last 30,000 years approximately, when much of northern Europe was under a kilometre of ice or more for much of the time. This illustrated how the ice sheets held an accumulated record of atmospheric composition as they formed. Analysis of the atmosphere trapped in ice cores shows that high salinity coincides with high levels of ice cover, corroborating the sea sediment evidence. Periods of higher average temperature coincide with higher levels of CO_2 and methane in the atmosphere, with these gases being trapped in ice during colder periods and released as ice sheets melt.

One perspective suggests that the changes can be explained simply by fluctuations in temperature leading to increased concentrations of the gas carbon dioxide (CO_2) in the atmosphere. Professor Boulton showed that well known and straightforward methods suggest that this is not the case: it explains only 0.5 degree Celsius change – 10% of the total change observable from the sediment and ice core evidence.

Fluctuations in the earth's surface temperature are more directly related to the composition of the earth's atmosphere, which operates like a thermostat. Evidence from the past 3 million years suggests that as the earth warms, CO_2 and methane build up in the atmosphere, trapping heat which would otherwise escape through the atmosphere, causing a greenhouse effect – warming in the lower atmosphere and on the earth's surface – and magnifying the temperature fluctuations.

Professor Boulton concluded this section of the lecture by saying that geologists had been largely agreed on these long term mechanisms and timescales for the last twenty years.

Turning to human life on earth during a glacial period, he showed through a series of slides [35-47] and perspectives that:

- Humans almost certainly hunted the mammoth to extinction.
- Civilisation was well advanced in Jericho 12,500 years ago when the location of modern day Glasgow was under a kilometre of ice.
- Past civilisations (Levant, Uruk, Egyptian and Mayan) have been known to founder as a result of changes in environmental conditions.

He reminded us that human population has risen from around a billion in about 1830 to approx 6.5 billion currently, and projections suggest that – barring accidents – there will be 9 billion humans by 2050. There has been significant improvement in some population health indicators during this period: average life expectancy is up from 46 to 64 years and the gap between richer and poorer nations has declined from 24 years to (a still disgraceful) 12 years. However, Professor Boulton argued that the question of how to feed 9 billion people will not be easily answered. Singular solutions of any kind will not suffice. It is likely that we humans have now outstripped the carrying capacity of the earth. Each individual now uses 14 times the energy which our hunter gatherer forebears used. It is even possible that the phrase 'sustainable development' has been damaging in trying to address these trends, since it gives the illusion of action when in fact little has taken place.

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Professor Boulton then turned his attention to natural resources and suggested that a number of diminutions had occurred. These included:

Deforestation

Looking at evidence from the Black Loch in Fife, he showed that human activity had accelerated deforestation as the development of arable and pastoral farming increased, assisted by a warming climate and retreating ice. This process peaked during the Bronze Age, and by Roman times, Europe was to all intent and purpose, deforested. This process reached its nadir in the UK in 1750 and more recently has been reversed a little by the planting of trees, largely for commercial purposes. In summary there has been a dramatic decrease in forest cover since the beginning of the current interglacial period, the human role in this has been extremely powerful and the fundamental nature of the environment has shifted.

Soil depletion

This is happening in two ways. Firstly, soil fertility is being depleted. At a planetary level, rich soils are to be found where one finds evidence of glacial or volcanic activity, both of which release essential minerals which are then broken down by weather and taken up by plants. In this sense, Australia and Central West Africa are barren and being made worse by human activity. Globally, over half of the nitrogen and phosphorous which finds its way onto soil is now artificial. Secondly, the planet loses vast quantities of soil every year. For example, last year about 20 billion tonnes of soil found its way into the South China and Yellow Seas because there is not enough forest vegetation to hold the soil in place. These days, we humans use up about 60-65% of the biological productivity of the continents for our own purposes, leaving little for other species. Similarly, 70% of all useable fresh water on the continents is intercepted, diverted and used for human purposes.

Hydrocarbons as fuels

Most observers agree that we have already or will soon pass the peak of oil production and that the price increases that we now see will be sustained and accelerated into the future. Cheap oil has been the basis of western economies for the past hundred years. It is questionable whether we can replace this in ways which will sustain our current lifestyles.

Atmosphere

Humans are now pouring large amounts of CO_2 into the atmosphere. Data from the ice cores show that levels of CO_2, methane and nitrous oxide have risen significantly above normal interglacial levels. If, as argued earlier, these gases are part of the earth's thermostat, such increases are cause for great concern. Data from the last hundred years do show significant rises in temperature on all continents. Satellite data from the last thirty years shows significant increases in mean surface temperature, particularly in northern latitudes.

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One can see the impacts of these changes for example in retreating glaciers, ice cover and melting permafrost and ice. These great sheets of ice are not susceptible to the warm weather of a single warm summer but show longer trends in heating and cooling. One effect of the current retreat will be the release of methane, CO_2 and other gases trapped in the ice, thereby accelerating global warming. This also has great significance for river flow. For example, something approaching 80% of the dry season flow of the Indo Gangetic plain comes from the previous season's snow fall in the high ranges of Ladakh. Without this snow, the dry season flow of India's great rivers will be about 20% of the current level. Similar processes are occurring in many river systems.

Forecasting of the effects of such changes is far from perfect, and is largely done through the development of computer simulations, complex in nature. While these have limitations, they are continuously improving and include the best of our scientific knowledge. Such models suggest that there has been clear *human* forcing of warming, over and above that of *natural* forcing, since about 1960. This pattern looks set to continue and we can see that:

- Despite all claimed effort, the rate of emissions has doubled since 2000.
- Empirical data from 2003 onwards suggest that the worst case carbon increase scenarios of the International Panel of Climate Change are being outstripped.
- This suggests there will be an increase in the global mean surface temperature approaching 7 degrees Celsius by the end of the century.
- The increase will be highest in Northern latitudes, where precipitation will also increase. It will decrease in sub tropical regions.
- Climate will be livelier – with faster, wetter storms in Northern latitudes.
- In the 2040s, the high temperatures ('heat wave') which caused excess deaths in Europe in 2003, will look normal; by the 2060s, they will look cool.

In addition, the North Atlantic sediment cores also suggest that there have been dramatic and unexpected changes in the earth's systems from time to time. For example, enormous volumes of methane hydrate are locked into the sediment of the continental shelves of the earth's oceans. In the past these have been released as temperature rises with a significant negative impact on carbon life forms through the acidification of the oceans bringing widespread, undesirable and long lasting consequences. In geological terms, such events and changes happen quite regularly and we would do well to remember that the earth's physical systems are dynamic.

In these circumstances, Professor Boulton proposed that we should think about *adaptation* and *response* to impact, alongside amelioration and aversion. We are most likely past the point of being able to avoid warming altogether.

In concluding, Prof Boulton suggested that he found it difficult to bring these issues to our attention, since they could be interpreted as a scare story. There may, for example, be processes in the earth's systems which inhibit the effects of warming. The question for us now is: how far are we prepared to risk that this might be the case? One interpretation of the lack of effective action to date is that we are prepared to engage in highly risky behaviour in relation the earth's systems. In policy circles science is often treated as if it is about certainty. He pointed out that science is more about uncertainty.

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For example, it may be that the effects of population growth which Malthus postulated in the 19th century are emerging now. Similarly, the Club of Rome suggested that a combination of population growth and resource depletion would lead to scarcity by 2000 as climate changed. Maybe they were wrong; maybe they were just out by a few decades.

The impact of such trends can already be seen in the earth's physical systems, and we are beginning to see their impact also on human populations. It is possible that we will begin to see the effects of these changes in Scotland in the next decade. If so, it will be difficult for existing methods and processes of living to deal with them.

At the level of governance it is likely that the nation state is insufficient to tackle this global challenge. Our current mindsets, locked into national boundaries and histories, make working together at global scale difficult. In addition, human beings "cheat". We might think that action is for others to take, since the emissions of Scotland are small when taken on a global scale. However, Professor Boulton illustrated the conundrum implicit in this approach using the example of vaccination: if you refuse to have your child vaccinated, you are depending on herd immunity to protect him/her, thereby depending on many others doing what you are not prepared to do.

Protection of the global commons – the earth's systems – upon which we all depend, requires something more than this.