From Anthropocene to Sustainocene – challenges and opportunities

Presented by Bryan Furnass to the ANU Emeritus Faculty 21 March 2012

Abstract

Geologists refer to the present post-glacial era as the Holocene, a period of relative climate stability which dates back for about 10,000 years to the human agricultural transition. At a climate change conference in 2000, Paul Crutzen, Nobel laureate in chemistry, was so alarmed by the evidence of human impacts on the biosphere since the industrial transition that he proposed that the present era be re-named the Anthropocene, marked by de-forestation and prodigious combustion of fossil fuels.

This paper is an amateur discussion of the origins and manifestations of the Anthropocene from bio-historical and health perspectives. The changes in environmental conservation and human behaviour which will be required to attain a sustainable future for humans and countless other species are so radical and urgent, that transition to a new era, provisionally termed the Sustainocene, is proposed.

An historical note on local atmospheric pollution

There are two reasons why I hope to make a small contribution to these complex issues. Firstly, having been trained in evidence-based medicine, I've found that the methodology for assessing the health of the environment is not so very different from that used in assessing the health of a patient. This involves taking a careful history of relevant past and recent events, conducting a physical examination, supported by special tests, such as temperatures, blood tests or gas samples and constructing a hypothesis for diagnosis, treatment and prognosis, with ideas about possible future prevention or mitigation.

The second reason is my personal experience of local air pollution. I was born and bred in the cradle of industrial civilization, namely the city of Manchester in Northwest England, where damp weather was good for cotton spinning. On several days during winter months, an acrid 'pea souper' smog would descend and be so thick that one could barely see one's hand on an outstretched arm. On foggy days, the only available form of transport was a tramcar preceded by a conductor carrying a flare, and followed by a queue of cars which finished up at the tram depot, since side streets were impossible to discern.

A similar experience occurred a couple of decades later, while I was working as a house physician in central London during the great smog of 1951. It was impossible to read street signs, and with no air conditioning, difficult to see across hospital wards. There were over 4000 deaths in London from respiratory failure over a single weekend, mainly involving patients who were already compromised by chronic chest disease. The government's eventual NIMBY response was the Clean Air Act, which banned the burning of coal in open fires and transferred pollution generation to coal-fired power stations in East Anglia, whence smoke drifted eastwards and fell as acid rain, destroying many Scandinavian forests.

In some rapidly developing countries, notably China and India, UNESCO has recently expressed concern over the rising adverse health effects on the respiratory system from local pollution, due to extensive coal combustion for industrial development. There is an added effect from petrol exhausts from internal combustion engines, particularly in cities such as Los Angeles and Bangkok, where sunshine contributes to photochemical smog. Even in London, air pollution is listed as currently listed as the fifth commonest cause of death, mainly from motor vehicle exhausts, an embarrassing observation this year when the Olympic Games are due to be held in London.

Global atmospheric pollution

A much more widespread and dangerous threat to human and planetary health is the annual release of billions of tonnes of carbon dioxide and other effluents into the global atmosphere from fossil fuel combustion since the industrial transition, which have influenced global warming through their greenhouse effect of trapping infrared radiant heat. During a climate change conference in 2000, Paul Crutzen, **(Fig 1)**, who had shared the Nobel Prize for Chemistry in 1995 for his observation of the depletion of the atmospheric ozone layer over Antarctica, declared that so extensive has been the damage to the biosphere caused by human activities since the industrial transition, that the present interglacial era, hitherto named the Holocene, should be re-named the Anthropocene. This proposal has been taken up by many climate scientists and is being officially considered by the Geological Society of London. 'Business as usual' is clearly unsustainable. So great are the changes required to avert disaster to people and other inhabitants of the planet that I propose to name the future era unofficially as the Sustainocene, in the forlorn hope that humans can reverse our destructive impact on our habitat.

The technology for the Anthropocene was launched by a Scottish engineer named James Watt, who invented the first effective coal-driven steam engine in 1754, which progressively replaced muscle power in factories **(Fig 2)**. There followed a mass migration of workers from farms to the 'dark satanic mills' of industrialized cities in Britain, accompanied by appalling working and living conditions, which generated a host of deficiency diseases and infections. These were first reported by Friedrich Engels in his classic publication *The Condition of the Working Class in England* (1845).

To facilitate transport of goods and people, George Stephenson in 1829 invented the first workable steam locomotive, named The Rocket **(Fig 3)**. This engine with carriages ran on the Liverpool-Manchester railway, opened by the Prime Minister of the day, the Duke of Wellington, and tragically killing a local MP on the same day.

An indication of how technical change has progressed over the past 180 years is the comparison between the Rocket in 1829, moving at 50kph and the world record speed of 574kph achieved by the French very fast train in 2007, run on a mixture of uranium-powered electricity and testosterone **(Fig 4)**.

Nuclear power

Since the development and deployment of nuclear weapons at the end of the Second World War, controlled energy release from nuclear fission of uranium has been promoted as a cheap supposedly non-polluting energy source for the Anthropocene, while continuing with the insane testing and accumulation of nuclear weapons for so-called defence purposes.

The carbon costs of nuclear power are underestimated, since they do not include the fossil fuels needed for construction and decommissioning of nuclear power plants and for disposal of nuclear wastes. The recent Fukushima disaster has also made the construction of new nuclear power plants problematical, although France (in a more stable geological environment) currently obtains 70% of its power from nuclear fission, while Germany has decided to progressively de-commission all of its nuclear facilities. It is a sobering thought that of the 400 nuclear power plants on the planet, only 17 have so far been de-commissioned. This is quite apart from the stockpiles of nuclear weapons, including rusting Russian nuclear submarines lying on the bottom of the Baltic Sea. So far there has been no internationally agreed safe way of disposing of radioactive materials, which remain as a ticking time bomb for thousands of years.

Optimistic nuclear scientists put their hopes on energy from nuclear fusion of hydrogen into helium, with little radioactive pollution, a reaction which is similar to the source of solar energy. Experiments are currently being carried out in France and USA using powerful laser beams to achieve fusion under conditions of immense temperature and pressure. If successfully applied on a practical industrial scale, this process could be a source of clean renewable energy worldwide, providing a transition to Sustainocene, on a par with James Watt’s contribution to the Anthropocene.

Global warming

On the global scale during the post-glacial era of the Holocene, the earth's atmosphere maintained its average of surface and oceanic temperatures relatively stable at around 14C through the trapping of the sun's infra-red heat by so-called greenhouse gases (GHGs), which make life on our planet possible. This mechanism was first proposed by the French mathematician Fourier, by the English scientist Tindale and organized on a scientific basis by Swedish physicist and chemist Svante Arrhenius (1859- 1927) **(Fig 5)**. The most powerful greenhouse gases are water vapour, methane and carbon dioxide, with minor roles played by oxides of nitrogen, ozone and CFCs. CO2 is the most stable of these gases, persisting in the atmosphere for centuries.

There has been an unprecedented exponential rate of increase of GHGs since the onset of the Anthropocene, particularly during the past half century **(Fig. 6)**.

The carbon costs of energy production show that coal combustion is by far the greatest polluter, more than twice that of gas and several times that of renewables **(Fig 7)**.

Climate scientists maintain that there is a causal link between anthropogenic GHG emissions and global warming, which has resulted from a combination of profligate combustion of fossil fuels and deforestation, in parallel with a rise in mean global temperature, calculated from terrestrial and oceanic thermometers located at different depths **(Fig 8).** The rise of average global temperature has been 0.8 degrees C over the past century, the greatest increase (2C) being in polar regions. Chief NASA scientist James Hansen calculates that the net gain in heat by the earth amounts to 0.6 Watt per square metre of surface, or the energy equivalent of exploding 400,000 Hiroshima sized atomic bombs every day for a year.

One dangerous result has been the melting of the Arctic ice cap, satellite photographs indicating that this has been more extensive than the highest of IPCC computer projections **(Fig 9)**. Extension of melting to the Western Antarctic ice shelf poses the alarming prospect of rapidly rising sea levels and storms, which will affect island and coastal communities worldwide. Loss of polar ice decreases the albedo effect of reflected heat, thereby increasing the rate of global warming by feedback. Another feedback mechanism has been the release of CO2 from melting ice and warming oceans, plus the release of methane from tundra and ocean depths, which renders the rate of global warming underestimated and unpredictable.

The main driver of global changes in the Anthropocene has been the exponential sevenfold increase in human population, which reached 6 billion in 2010 **(Fig 10)**, and 7 billion in 2011, in parallel with extrasomatic energy use, mainly from fossil fuel combustion **(Fig 11).** Thanks to public health advances and developments in agriculture, the Anthropocene has provided food security, reduction of infectious diseases and a doubling of life expectancy, from forty to around eighty years in industrialized countries. This has been accompanied by a fall in birth rates and a pronounced increase in the ageing of the population. Paradoxically, these apparent benefits have induced anxiety in some developed countries concerning constricting economic growth, the decline of the local workforce and the rising cost of healthcare for the elderly in their declining years.

Demographic studies have shown that the most important predictor of population health in developing countries is female literacy in childhood, designated by primary school attendance. Health improvements include reduced infant mortality rates, increased life expectancy and reduction in family size.

Inequalities in energy use are apparent from the compound photographs of earth at night, taken by NASA from space **(Fig 12)**. Densest areas of light are seen in Europe, North America, parts of the Middle East and Japan, and coastal areas of south Asia, which have been the major contributors to climate change in the Anthropocene, through massive fossil fuel combustion. Most of central Africa, South America northern Asia and central Australia remain dark. Africa is now the locus of the most rapid population growth, predicted to exceed one billion before the end of this century. Interestingly, this map overlaps the demographic picture of life expectancies, comparing the industrialized and developing world, exceeding 80 years in much of Western Europe, Canada, Japan and Australasia. US life expectancy falls below this figure, which, despite its excellence in medical technology, has an inequitable health care system which is unaffordable by the poor, notably blacks and Hispanics.

Recent initiatives in Central Africa and South America include the introduction of photovoltaics and storage batteries to villages. This source of non-polluting renewable energy directly from sunlight has provided light for reading, access to the internet and heat for cooking. In consequence, this has enabled many previously illiterate children, particularly girls, to become literate, some of them to the point of being able to achieve a university education. So photovoltaics may be regarded as an effective form of contraception in developing countries, although several Islamic nations do not permit girls to attend school. (The opposite effect was observed in USA a few years ago when a power failure in New York led to a spike of births nine months later by couples who had sought an alternative form of entertainment to television viewing!).

The history of the biosphere

The distant origin of the health of the planet can be found in the history of the biosphere **(Fig 13)**. The Earth’s early atmosphere was composed of carbon dioxide, nitrogen, methane and water vapour, with no oxygen. Chlorophyll appeared in blue-green algae around 3.7 billion years ago. It converted CO_2 and water into sugar, releasing oxygen as a by-product, using the sun's energy through the process of photosynthesis**,** according to the following equation: $6H^*_2O+6CO_2=C_6H^*_{12}O_6 +6O_2$. (*represents "excited" electrons pushed into wider orbit by photons, and captured by intracellular electron transport systems). Sugar was then converted into fibrous carbohydrate structures for the growth of plants, whose decayed remains were, over hundreds of millions of years, eventually converted into fossil fuels. The reverse of the photosynthesis equation occurs in respiration and combustion, with the release of CO_2 and the stored energy gained from sunlight. Life forms for the first three billion years of the history of the biosphere entirely comprised micro-organisms, during which time the earth's atmosphere was converted to its present composition of 79% nitrogen, 21% oxygen and (pre-industrial) 280ppm carbon dioxide. An ozone layer was formed which protected emerging multicellular plants from excessive ultraviolet light exposure.

Under tremendous pressure, oil deposits were formed from algae, and coal and natural gas from masses of cycads during the Permian and Carboniferous eras, 3-400 million years ago. These fossil fuels have been combusted at increasing rates during the Anthropocene. The oldest known fossils representing early photosynthesis can be found as stromatolites on seashores and the Pilbara region of Western Australia **(Fig 14)**.

Chlorophyll and DNA are the most important complex molecules on the planet. The structure of chlorophyll a is portrayed in **Fig 15**, and a cartoon picture in **Fig 16**, with a central magnesium atom, surrounded by a necklace of nitrogen and oxygen atoms, and a pendant of carbon and hydrogen.

The woodland in **Fig 17** represents chlorophyll in action, ten trees providing enough oxygen for the respiration on one human. During the Anthropocene, humans have destroyed one half of the earth's forests, and are continuing to do so, illegally, in SE Asia and the Amazon.

Forest destruction removes not only trees, but the many ecosystem services which they provide, from the soil's carbon sink and innumerable plant and animal species, including this rainbow lorikeet **(Fig 18)**.

In the context of the history of the biosphere, humans are new kids on the block, hominids appearing about 5 million years ago, and the species *Homo sapiens* (so-called) about 200,000 years ago **(Fig 19)**. For well over 90% of their time on this planet, our ancestors were hunter-gatherers.

Despite their limited life expectancy, due to deaths in childbirth, external violence from predators or prolonged droughts, hunter-gatherers needed to be remarkably fit and resilient in order to survive **(Fig 20)**. According to Stephen Boyden, optimum health is achieved through the evolutionary health principle, namely by following the lifestyle of our hunter-gatherer ancestors to which they had become adapted through evolution.

According to Stephen Boyden, optimum health is achieved through the evolutionary health principle, namely by following the lifestyle of our hunter-gatherer ancestors to which they had become adapted through evolution. Nutrition has drastically changed in the Anthropocene **(Fig 21)**. Early white settlers employed Aboriginal men as stockmen, and in lieu of wages provided them with sacks of white flour, sugar and tea, completely at odds with their traditional healthy varied diet.

A few years ago a professor of nutrition, Karin O'Dea, from Deakin University, planned an experiment on a group of Aboriginal people living in a suburb of Perth, who had adopted typical Western lifestyles and consequently developed typical western diseases, including obesity, hypertension, Type 2 diabetes and alcoholism. O'Dea persuaded some Aboriginal elders to lead a group of these suburbanites through the Western Australian desert, their only water and food sustenance being obtained from the bush. After six weeks of following the hunter-gatherer lifestyle of their ancestors, the study group returned to Perth for re-assessment. Their morale and physical fitness had greatly improved, and there were substantial reductions in body weight, blood pressure, blood sugar and cholesterol levels, indicating that the metabolic syndrome is reversible through lifestyle changes.

Environmental impacts of the Anthropocene

Since the onset of the industrial transition in the late 18^{th} century, the human population has grown in step with fossil energy use and with gross domestic product **(Figs 10&11)**. Coal mining and oil exploration have been encouraged by unlimited mining and oil exploration rights and fossil fuel subsidies Despite the scientific evidence of the dangers of anthropogenic global warming due to fossil fuel combustion and deforestation, both industrialized and developing countries continue to plunder coal reserves and construct coal-fired power stations. Particularly damaging to both local and global environments are the practices of extracting tar sands for oil in Canada, 'fracking' of agricultural landscapes for coal seam gas, deep dredging for a North Queensland port adjacent to the Great Barrier Reef to carry coal shipping transports and massive (illegal) destruction of rain forests in South America and Southeast Asia. These practices are reinforced by denialism, particularly by right wing political groups who reject the scientific evidence that humans are the cause of global warming, and place short term profits ahead of threats to the survival of the human species **(Fig 22)**.

"Achievements" of the Anthropocene include loss of terrestrial and oceanic biodiversity, pollution of the atmosphere by particulates, CO_2, CFCs, oxides of nitrogen and many other gaseous products, creation of oceanic “dead zones” and resource depletion of fish, oil and agricultural chemicals such as phosphates (**Fig 23)**.

Impacts of the Anthropocene on human health

In terms of physical health and wellbeing, humans in the Anthropocene are undoubtedly better off than they were in mediaeval times. Housing standards have improved, the ‘sanitary revolution’ of the 19th century provided clean food and water supplies, reducing the incidence of gastro-intestinal infections, maternal mortality and infant death rates. As a result, life expectancy at birth has increased from about 40 to above 80 years in many developed countries, aided and abetted by inoculation against many infectious diseases, modern medicine, anaesthetics and improved surgical techniques which were undreamed of a century ago **(Fig 24)**.

Unfortunately there are negative sides to these gains. Unlimited access to foodstuffs, particularly those including fats, low-satiety sugars and refined carbohydrates, combined with a marked reduction in physical activity for work, transport and recreation has led to a widespread epidemic of the so-called metabolic syndrome, comprising obesity, Type 2 diabetes and cardiovascular disorders, such as coronary heart disease, hypertension and strokes. Hospital care has been compromised by the appearance of multi-antibiotic resistant infectious diseases due to excessive prescribing of antibiotics both in humans, and to a much greater extent in livestock as so-called growth promoters (although Danish studies have shown that they are ineffective for this purpose). It is ironic that the first use of carefully harvested penicillin by Nobel laureate Howard Florey against a case of *Staphylococcus aureus* osteomyelitis, while initially successful, was aborted when the supply of the antibiotic ran out. We now face the dilemma, as the chief of the World Health Organisation has warned, that we may be approaching a post-antibiotic era of medical practice of rising mortality rates from multi-antibiotic resistant bacteria. In developing countries, the spread of multi-resistant tuberculosis and malaria poses a similar threat. In the case of the emergence of malaria and other vector-borne infectious diseases to wider latitudes as a result of global warming this is also likely to pose a threat to northern regions of Australia. Global climate impacts include extreme weather events and threats to food and water security, breakdown of social and material infrastructures and rioting and warfare for resources (**Fig 25**).

A gloomy viewpoint on the Anthropocene has been published as the Oldulvai theory of civilization **(Fig 26)**, in which a headlong rush to fossil fuel use and resource depletion starts with James Watt’s invention of the steam engine and plunges downwards until only 37% of oil reserves remain. This drawing will need to be modified in view of civilisation’s addiction to oil, which now includes the dangerous and inefficient practices of deep sea and Arctic oil exploration and the proposed extraction of oil from Canadian tar sands.

Adaptive changes towards Sustainocene

The cultural changes required to rescue the human species and the rest of the biosphere from the injuries inflicted by the Anthropocene are so great that a required new era might be designated by the (geologically incorrect) name of the Sustainocene. The hallmarks of this era must include a transition from a 19^{th} century polluting carbon economy from combustion of ancient stored solar capital into a photon economy, which maximizes the use both directly and indirectly of the endless clean energy currency from the sun. This must also include the preservation of oceans, soils and vegetation, which act as nature’s carbon sinks. In economic terms it will entail a radical transformation of our notions of “progress” from the current obsession with gross domestic product (GDP), which is really gross domestic profligacy into Genuine Progress Indicator (GPI), which embraces reduction of inequalities, environmental protection and sustainability **(Figs 26&27)**.

Aspirations of a “photon economy” for the Sustainocene

There are two main types of energy from photon converters. The first is photovoltaic silicon-based cells which convert sunshine directly into electricity, mainly for domestic and local manufacturing capability. Technology in this area is going ahead in leaps and bounds to improve efficiency and reduce silicon use and costs **(Fig 28)**.

The tiny kingdom of Bhutan in the Himalayas has gone one step further and proposed Gross Domestic Happiness as the true aim of progress at the human level, **(Fig 29)**. In view of the world’s “suicidal path”, Bhutan’s prime minister Jigmi Thinley has offered to host an international forum on happiness, as an alternative to our growth-based economy.

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and local manufacturing capability. Technology in this area is going ahead in leaps and bounds to improve efficiency and reduce silicon use and costs.

A local example is the sliver cell technology developed by Andrew Blakers at ANU's sustainable energy technology unit. Although photovoltaic units have been installed in many Australian homes and public buildings, the rate of installation has been slowed by the government's withdrawal of feed in tariffs. Not so in Germany, where despite its lack of sunshine, many homes have been fitted with photovoltaics, a major stimulus for this being the country's decision to abandon nuclear fission as an energy source.

The second main type of solar energy conversion is solar thermal electricity (STE). This resembles James Watt's steam engine, except that instead of using coal combustion as an energy source, the sun's rays are reflected by mirrors on to either a tower or linear tubing to convert water into super-heated steam which drives a turbine and hence a generator connected to an electricity grid. The principle of this technology was first developed by physicist Professor David Mills of Sydney University, who developed vacuum tube solar hot water systems for domestic use, backed by gas generators to ensure a round the clock hot water system. Unfortunately his attempt to commercialise this system in Australia failed because of lack of industry, government or business support. A Chinese member of his team took the technology to Shanghai, where he manufactured millions of vacuum tube solar hot water systems for Chinese roofs, and has become a multi-billionaire, and one of the richest men in China. If one wishes to install this efficient type of solar hot water system it has to be ordered and delivered from China. This is an example of Australian expertise being exported overseas rather than being commercially developed at home. **Fig 31** illustrates the solar plant in the Mojave desert in California, where sunshine is reflected on to a steam turbine mounted on a tower.

Fig 32 is a solar furnace in the French Pyrenees, capable of attaining temperatures of 3800C.

Fig 33 represents the principle of Mills's Fresnel linear solar reflector, in which photons focused on a horizontal pipe convert water to superheated steam.

The application of this principle to a projected field in California to generate 177 Megawatts of electricity by a compact Fresnel linear reflector (CFLR) appears in **Fig 34** (I Megawatt = 1 million watts).

A similar "Solar Dawn" device to generate 250 Megawatts of electricity is planned for Chinchilla in western Queensland, as part of the federal government's $10 billion Clean Energy Finance Corporation scheme to encourage clean renewable energy generation. It includes a supplementary gas turbine to ensure round-the clock power supply.**(Figs**

35 & **36)**. The ACT government is planning two 20 Megawatt solar energy generators to pursue its 20% reduction in carbon emissions for Canberra by 2020.

It is a constant refrain of fossil fuel industries that renewable energy (including solar generated electricity) only supplies about 2% of the needs of industrialized countries, and that undue investment in them would only lead to economic collapse. This claim has been refuted by David Mills, who claims that application of STE is already economically competitive with imported oil, and that capital investment of up to $1500 billion dollars over several years could reliably supply the whole of the US base load electricity grid plus the requirement of an electrically driven transport system, with a storage capacity of only 16 hours, backed by gas turbine generators to meet excessive peak loads **(Fig 37)**. The system is also applicable to developing countries with sunny deserts, such as in the Middle East, China, India, Brazil, and of course Australia.

Globally, according to the Australian Conservation Foundation (ACF), 2011 marked the first time that the $260 billion invested globally in renewable energy outstripped investment in fossil fuel energy. As the world's greatest per capita carbon polluter, Australia's slice of the pie was disappointingly small at $10 billion investment, albeit a huge step up of 60 per cent on the previous year. Countries such as China, South Korea, Germany and the US are leaving us for dead in the race for renewable energy – often using technologies that were developed here. Clearly our abundant supplies of coal and gas, coupled with vast vested interests and ideological drive towards an unsustainable future are holding us back. ACF estimates that we need up to $100 billion of investment in new clean energy in the next decade alone simply to meet the minimum (and insufficient) five per cent emissions reduction target. At the local level, over 500,000 homes (out of a total estimated 7.5 million homes in Australia) have installed solar panels. **Fig 38** illustrates a north facing 1.5Kw array of photovoltaic panels, vacuum tube solar hot water heater and evaporative cooler.

Indirect forms of solar energy generation which are available in abundance in Australia include wind, hydro and wave power, together with tidal gravitational power from the moon, and largely untapped geothermal power from nuclear reactions in the earth's core. These opportunities to convert to a low carbon economy by the end of the century could create hundreds of thousands of jobs, while playing our part in lowering the risks of potentially catastrophic manifestations of global heating when average global temperature rise exceeds 2C. The technologies are available, but the main obstacles lie in denial of the problem, vested interests in the status quo and government inertia.

According to the *United Nations Secretary General's High-Level Panel on Global Sustainability (2012)*: " We must recognize that the drivers of that challenge include unsustainable lifestyles, production and consumption patterns and the impact of population growth. As the human population is predicted to grow from 7 billion to almost 9 billion by 2040, and the number of middle class consumers increases by 3 billion over the next 20 years, the demand for resources will rise exponentially. By 2030, the world will need at least 50 per cent more food, 45 per cent more energy and 30 per cent more water – all at a time when environmental boundaries are throwing up new limits to supply. This is true not least for climate change, which affects all aspects of human and planetary health". Challenges for the Anthropocene may be summarized as the 'Five Ps', namely Population, Poverty, Pollution, Profit and Preparation for War (**Fig 39)**.

The opportunities to transform the human trajectory towards the direction of a Sustainocene may seem unduly idealistic or utopian, involving as they do a change in mindset as much as in behaviour. But they must at least be attempted if we have any concern for the future of our grandchildren, who will otherwise justifiably and roundly condemn us for many of the disasters which beset humankind. The required changes in mindset might be summarized as the four E's, namely Enlightenment, Ecology, Education and Ethics **(Fig 40)**.

Ethical behavior, referred to by Aristotle as the pursuit of virtue in his *Nichomachean Ethics*, is seldom near the top of the list for industrialized or developing nations, or amongst their citizens, having been almost universally replaced by the profit motive and economic growth as the main drivers of societal development. Drug manufacturers and arms peddlers head the list towards this nadir of so-called civilisation

In philosophical terms, the ABC of enlightenment may be seen as a sea change in human thinking towards Awe, Beauty and *Caritas* **(Fig 41)**. Dr Samuel Johnson preferred the Latin word *caritas,* which means care with acted responsibility towards people and nature to the more passive word compassion. Caritas has been adopted by a Catholic charity organization, which is doing good practical work amongst socially, emotionally and physically deprived people.

Whether or not one is religiously inclined, the instrument for change is the human cerebral cortex, which Richard Dawkins has described as the most complex structure in the known universe **(Fig 42)**. The brain must be used both in individual and collective lifestyle choices towards a sustainable future for our descendants, if the human species is to become a creative rather than a destructive influence on the biosphere.

Fig 43, a photograph of the Horsehead nebula in the constellation of Orion, is about 1400 light years away, quite close in cosmic terms. The red glow is the spectrum of hydrogen, the commonest atom in the universe, and the blue colour is due to a flush of electrons, indicating that we inhabit an electric universe. Our local star, the sun, is one of 100 billion other stars in the Milky Way, which is one of 100 billion other galaxies.

Photons from the sun's centre take 100million years to reach its surface and another eight minutes to reach the earth. This should remind us that since every atom of our bodies is derived from the Big Bang, that we are children of the universe.

The secular view is that we are one of tens of millions of other species, and part of the biosphere, **(Fig 44)** our brain conferring on us a special responsibility to preserve rather than destroy the integrity of our habitat, if only for the selfish reason that human survival, health and wellbeing is entirely dependent on the health of the natural environment.

There are many examples of awareness of the situation and moves towards local mitigation activities, particularly by the younger generation, who have most to lose from the environmental crisis that we now confront. An orthopedic surgeon who is also a lifesaver in the coastal town of Bega (NSW), organized a community demonstration to raise money to ensure that every NSW lifesaving hut should have photovoltaic panels mounted on its roof. 3000 people (about 10% of the population of Bega) turned up for an aerial photograph on Tathra beach **(Fig 45)**.

High school students from nearby Narooma high school were also persuaded to demonstrate a message in Mandarin , "to our future", perhaps prophetically deferring to the rising superpower **(Fig 46)**.

The growing of fresh food supplies, from farmers' markets to primary school vegetable gardens is also becoming popular, requiring fewer fossil fuels for inorganic fertilizer and transport for local distribution, as was the case in the "dig for victory" campaign in wartime Britain. This may become a necessity in Australia and elsewhere if climate change poses threats to industrial scale food production.

In Greek mythology, the god Zeus created the first mortal woman, named Pandora, meaning "all gifts", to whom he presented a box or jar. When the lid was removed, all the demons which beset humankind flew out, leaving only Hope behind in the bottom of the box. **(Fig 47)**.

There have been innumerable conferences on climate change to discuss the critical environmental situation which we now confront. In this centenary of the sinking of the Titanic, which blundered unheedingly towards disaster, despite warnings, was well summarised in a cartoon created following the Bali conference on climate change **(Fig 48)**. Iceberg avoidance in the anthropocene will require "Thinking and acting both globally and locally".

The 16th century engraving of Spes, or Hope **(Fig 49)** who remained in the bottom of Pandora's box shows that one prisoner has been liberated from the stocks, representing scientific discoveries, cultural development and almost limitless ingenuity of the human mind to solve problems and to adapt to changing circumstances. The remaining prisoner is beset by denialism, parochialism, short-sightedness, vested interests in destructive activities, and a propensity to suicide, homicide and biocide.

Conclusion

- Humans have been extraordinarily successful in obeying the injunction of *Genesis* to*"* be fruitful and multiply….and have dominion over every living thing that moveth upon the earth", during the era which followed the last ice age, and named by geologists as the Holocene, of relative climate stability

- The domination by *Homo sapiens* has been intensified since we harnessed the ancient remains of solar energy stored by chlorophyll as fossil fuels to machines for agriculture, manufacturing, transport and fighting wars. In this process we largely disregarded, and indeed usurped, the needs of the biosphere on which we are entirely dependent for our survival, health and wellbeing, justifying the re-naming of the present era as the Anthropocene

- Although the Anthropocene has conferred many benefits on the minority of industrialized societies in terms of improved health and material living standards, it has jeopardised the sustainability of our own and countless other species through anthropogenic global warming, loss of biodiversity, gross inequalities and depletion of non-renewable natural resources

- Although Australia has been one of the most favoured nations in terms of natural resources, including brain power, we have had one of the most destructive impacts on the integrity of the biosphere. Successive governments have been extraordinarily obtuse in failing to recognise the environmental crisis which we now confront and to address our responsibilities and opportunities to achieve a sustainable future for our descendants

- The transition required to meet our challenges and opportunities is theoretically possible, given the social and political will, to create a new era, called the Sustainocene, which will require transformation from an anthropocentric to a biosensitive society, re-kindling recognition of our inter-dependence with the natural world.