Introduction

Towards the end of the 17th century and during the 18th century, the intellectual movement commonly referred to as the Enlightenment was underway in Europe. This movement emphasised rational thought, as opposed to religious tradition, as a means of understanding the universe and improving the human condition.

This fourth cultural watershed paved the way for the fourth, Exponential Phase of human history — a phase that is associated with further profound changes in the ecological relationships between human populations and the rest of the biosphere. Especially significant ecologically were the introduction of machines that used extrasomatic energy from fossil fuels for performing various kinds of work and the enormous growth of the chemical industry. Also of great importance was the discovery and application of electricity, radioactivity and radio waves.

There have also been important scientific advances that have resulted in a massive growth in the human population. There are now about 1,500 times as many people alive as there were when farming began. Nearly 90 per cent of this increase has occurred in the Exponential
Phase of human history. This vast increase in the number of people on Earth is putting immense pressures on the food-producing ecosystems of our planet.

**Cultural maladaptation**

Cultural maladaptations in ecological Phase 4 are manifold. Some affect humans directly, while others cause damage to the living environment on which we depend. At present, some even pose a threat to the survival of civilisation, perhaps of the human species.

Over the past 150 years, new knowledge coming from the sciences has often led to warnings about the undesirability of maladaptive activities, setting in motion cultural responses aimed at overcoming the cultural maladaptations. This process is referred to as cultural reform.

Cultural reform is complicated and involves prolonged interactions between different interest groups in society. A key role is often played initially by minority groups, occasionally by single individuals, who start the ball rolling by drawing attention to an unsatisfactory state of affairs. A good example is Rachel Carson, who, in her groundbreaking 1962 book *Silent Spring*, drew attention to the insidious and destructive ecological impacts of certain synthetic pesticides.

Almost invariably, these expressions of concern coming from reformers are promptly contradicted by others, the counter-reformers, who set out to block the reform process. This predictable backlash often involves, but is not restricted to, representatives of vested interests who believe that the proposed reforms will be to their disadvantage. They are likely to argue that the problem does not exist or that it has been grossly exaggerated, and they try to ridicule the reformers by calling them alarmists, fanatics, scaremongers and prophets of doom. Nowadays some of the counter-reform forces are extraordinarily powerful.

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Eventually, if the reformers are successful, a change comes about in
the dominant culture and members of government bureaucracies
and other organisations set about working out ways and means of
achieving the necessary changes. Their efforts may still be hindered
by the stalling tactics of counter-reformers.

Cultural reform may be corrective or antidotal. Corrective reform
occurs when the adaptive process involves correcting the underlying
cause of maladjustment or disharmony. An example is provided by
the restoration of vitamin C to the diet of a population suffering from
scurvy. In antidotal reform, the unsatisfactory conditions that are the
underlying cause of disturbance are not modified, and the adaptive
response is aimed at alleviating the symptoms or at an intermediate
factor. Most, but not all, of the work of the medical profession
is antidotal rather than corrective.

Some examples of serious cultural maladaptation in the Exponential
Phase will be discussed below.

**Life experience**

In the year 1900, around 20 per cent of the world population lived in
cities. By 1989 the proportion had grown to 40 per cent. Today it is
greater than 50 per cent and about half of all urban dwellers live in
cities with populations of 100,000–500,000. Less than 10 per cent live
in cities with populations of more than 10 million.

One of the notable differences between the lifestyles of modern city
dwellers and those of their hunter–gatherer ancestors is the clear
distinction in the present setting between work and non-work
activities. Linked with this is the fact that there has been a progressive
trend for people to become further and further removed from the
end product of their efforts. Individuals employed as computer
operators may be playing an essential role in outcomes as diverse as
manufacturing ammunition and protecting biodiversity.

Other significant changes in human behaviour include:

- spectacular increases in the speed and distance of human travel
- widespread instantaneous electronic communication between
  humans across the world
most adults now perform much less physical work than the typical hunter–gatherer (although there are some exceptions, such as marathon runners and some farm workers)

for many people, much of their physical activity is unnaturally repetitive (e.g. computer operators, professional violinists)

most people now spend several thousand hours a year sitting still and staring at the rectangular screen of a television set or computer.

Another important psychosocial change is the lengthening of goal-achievement cycles. In the natural environment most goals were set for a few hours — or at most a few days. In present society goals are often set for many years ahead.

An all-pervasive feature of affluent societies in the modern world is consumerism, which seems to make a definite contribution to human well-being. For many individuals, the act of purchasing manufactured goods is an important source of enjoyment, tending to counter the undesirable effects of various environmental stressors. A common and often effective response to a feeling of depression is a shopping spree. Consumerism has perhaps come to replace, or compensate for, more biosphere-friendly forms of enjoyment that were important in earlier societies, such as the experience of conviviality and various kinds of creative behaviour and activities that resulted in a sense of personal involvement and purpose.

Differences in material wealth are extreme and are increasing in many nations, including the United States, Australia, the United Kingdom, India and China. The 125 richest people in the world possess assets greater than all the least developed countries combined. In Australia, the income of senior executives is 150 times average weekly earnings; and the seven richest Australians hold more wealth than 1.73 million households in the bottom 20 per cent range.
Human health

Infectious disease

The public health movement in Britain, which began in the early 1800s, is an early and well-documented example of cultural reform. A small group of reformers, consisting mainly of young medical doctors who were well aware of the appalling life conditions of the working class in the new industrial towns, called for profound improvements in urban sanitation and housing.

The efforts of these reformers were promptly countered by counter-reformers in the form of rich landlords and representatives of water companies, whose financial interests might have been threatened by government action aimed at alleviating the situation. While this backlash slowed down the reform process, major and effective reforms eventually came into place, beginning with the Public Health Act of 1948.

Since that time there has been a spectacular drop in the incidence of serious contagious diseases and malnutrition, especially in developed countries. The following factors have been especially important:

- *greatly improved sanitation*, which reduced the likelihood of contact with disease-producing organisms spread via human excreta
- *improved nutrition*, leading to a greater resistance to infection
- *artificial immunisation*. This was first introduced in Britain in the late 18th century in the case of smallpox, but is now applied to a wide range of infectious agents. It has resulted in a significant drop in the incidence of many infectious diseases. Indeed, it led to the actual elimination of smallpox in 1979. Rinderpest, a serious virus disease of cattle and other ungulates in Africa has also been eradicated as the result of an effective vaccination campaign
- *the introduction of antibiotics*, which has further reduced mortality from bacterial infections.

At the present time, some disease-causing bacteria, including ‘golden staphs’ and bacteria responsible for tuberculosis and pneumonia, are developing resistance to previously effective antibiotics. This is becoming a very serious problem.
There is still room for big improvements in the developing world. It is estimated that over 1 billion people do not have access to safe drinking water. Adequate sanitation is not available to 2.5 billion people.

Although there has been an impressive drop in the incidence of serious bacterial disease in the developed countries, modern populations the world over are exposed to an ever-increasing number of viruses that cause relatively mild diseases, like the common cold, influenza and various gastro-intestinal disturbances. These viruses need a large contiguous human population to keep them going, and they could not have survived before the advent of towns and cities. But current conditions suit them well and, as new viruses arise, there is nothing to stop them circulating around the global population of humankind ad infinitum. There are now hundreds of these viruses in existence.

Some scientists believe there is a strong likelihood that further new viruses with high mortality rates will emerge in the future, spreading rapidly through the global population.

Nutrition

As a result of improved scientific understanding of the nutritional requirements of the human species, urban populations are now much better nourished than was the case a couple of hundred years ago.

Significant deviations from the natural, or evolutionary, diet are still, however, the cause of much unnecessary ill health. Overeating is a major problem. According to the World Health Organisation, in 2013 obesity had doubled worldwide since 1980. In 2008, 35 per cent of adults over the age of 20 were overweight, and 11 per cent were obese. In 2011, 40 million children under five years old were overweight. In Australia 60 per cent of adults and one in four children are now overweight. Excess body weight is known to contribute to cardiovascular disease, diabetes, osteoarthritis and some kinds of cancer.

Other deviations from the natural diet that contribute to ill health include the consumption of refined carbohydrates and the absence of sufficient plant fibre in the diet.
Incidental contamination of food with the chemical products of industrialisation has proved a serious problem over the past half century. Contamination with pesticides, such as DDT and its breakdown product DDE, has been especially significant. Another common contaminant is polychlorinated biphenyl (PCB), which is used for various industrial purposes.

In the developed countries there has been growing awareness of the risks associated with chemical pollution of foods, leading to government regulations aimed at controlling the use of potentially toxic substances.

Turning to deliberate additives, countless different chemical substances are put into human food for various reasons. The most widely used of these is sodium chloride (salt), which humans have added to their food since ancient times. The majority of people in our society consume 10 to 15 times more salt than is necessary to satisfy their physiological requirements. A strong body of medical opinion holds that this deviation from the natural diet is responsible for much of the high blood pressure that is common in modern societies.

In 1820, Friedrich Accum, a German chemist living in London, published a *Treatise on adulteration of food* in which he denounced the use of chemical additives in food. This was a groundbreaking work and his book sold well. One of his concerns was the practice of adding alum to bread to make it look whiter. There was a vicious backlash from counter-reformers, however, in the form of bakers and millers, and Accum received many threats to his life. He eventually left London to return to his homeland.

Many years later, the validity of Accum's claims was confirmed and legislation was introduced aimed at preventing adulteration of bread with any officially unapproved substance.

Today, commercially prepared foods contain a wide range of additives with specific functions, such as preservatives, anti-oxidants, colouring agents, flavouring agents, sweeteners, filling agents, stabilisers, emulsifiers and other ‘improving agents’. The battery of flavouring agents in today’s commercial food products includes well over a thousand different chemical compounds.
The advances in nutritional science over the past hundred years, including the discovery of vitamins and essential amino-acids, represent one of the most impressive chapters in the annals of scientific research, and they have contributed immensely to human health and well-being. On the other hand, it is sobering to bear in mind that no knowledge of the existence, chemistry or biological function of vitamins or any other nutrient is necessary for the avoidance of nutritional deficiency diseases. All that is required is, first, understanding of the evolutionary health principle (Chapter 2); and second, knowledge that the typical diet of *Homo sapiens* in the natural habitat of the species consisted of a wide variety of different kinds of fresh vegetables, fruits, nuts and roots, and some cooked lean meat.

**Alcohol consumption**

No doubt some of our hunter–gatherer ancestors had the occasional meal of fermented fruit leading to a pleasurable feeling of mild intoxication. Once humans adopted the farming lifestyle, however, they lost no time in learning how to brew alcoholic drinks. It seems that, at least by 9,000 years ago, grapes, berries, honey and rice were being used to produced alcoholic beverages in northern China, while people in the Middle East were making barley beer and grape wine.

Wine drinking was a feature of ancient Greece, where people who did not drink wine were considered barbarians. Alcohol consumption was also common in ancient Egypt and Rome. But it is notable that in all these cultures, drunkenness was deplored, except in the case of certain religious festivals. Moderation was the law of the day.

Before the Middle Ages, the main alcoholic beverages in Europe were beer and wine. Distillation leading to the production of spirits like gin, vodka and whisky became widespread in the 15th century.

The Christian Church in Europe in the 16th to 19th centuries considered alcoholic drinks to be a gift from God — to be enjoyed for pleasure and health reasons — but again in moderation. Drunkenness was seen as a sin.

Less is known about the history of alcohol production and consumption in the Americas, although a wide range of alcoholic beverages from different plants were known to the indigenous inhabitants before contact with Europeans.
Today there is big variation among different countries in alcohol consumption. For instance, the per capita consumption of pure alcohol in Austria, Ireland and France is about 12 litres per year, while in Mexico it is 5.3 litres; Israel, 2.4 litres; and Turkey, 1.6 litres. In Australia, the United Kingdom, and Switzerland it is about 10 litres.

The effects of alcohol consumption on the human organism are well known. On the positive side, it gives rise to an enjoyable state of mind and it facilitates pleasurable social interaction. In many situations, the consumption of alcohol can be seen as an adaptive response to the requirement of modern society that individuals interact with a large number of complete strangers. Under the influence of alcohol, natural reserve and suspicion give way to an atmosphere of relaxed conviviality. Also on the positive side, if the statistics can be believed, is the fact that people who drink a moderate amount of alcohol regularly are likely to live longer than those who abstain.

On the negative side, the consequences of heavy drinking include lack of coordination, blurred vision, interference with judgement and sometimes, but not inevitably, aggressive behaviour. It is estimated that 50 per cent of road accidents in Australia are due to the overconsumption of alcohol. Excessive alcohol consumption has a range of other undesirable consequences. These include loss of jobs, family disruption, memory loss and various physiological disorders like cirrhosis of the liver. It also increases the likelihood of some forms of cancer.

**Tobacco smoking**

The story of tobacco smoking provides a good example of cultural maladaptation, cultural reform and cultural counter-reform. Right from the early days of smoking in Europe, occasional individuals intuitively felt that this unnatural behaviour was not a good thing. One such person was King James I of England (James VI of Scotland). In 1604 he described tobacco smoking in the following words:

> A custom loathsome to the eye, hateful to the nose, harmful to the brain, dangerous to the lungs, and in the black, stinking fume thereof, nearest resembling the horrible Stygian smoke of the pit that is bottomless.²

In fact, from the 16th century onwards, smoking was banned in many Catholic churches throughout Europe and in Mexico. Smoking was banned in several European cities, including Berlin, in the 18th and 19th centuries. In the early 1940s, the Nazi regime mounted antismoking campaigns and attempted to restrict smoking in government offices, universities and some hospitals.

The reform movement was boosted by the epidemiological studies of Richard Doll and his colleagues in the early 1950s, which showed without doubt that tobacco smoking is the cause of a great deal of ill health and early mortality. The predictable counter-reform backlash from vested interests was, however, still active some 20 years after this work. I have in my possession a pamphlet from that time that was distributed by the Australian cigarette industry as ‘an information service to smokers’. On the front page there is a single quotation as follows:

The concept that smoking is the cause of the increase in lung cancer and emphysema is a colossal blunder.

Inside the pamphlet there are a few more quotations by members of the medical profession, taken from a public enquiry into smoking and health before the 1969 Committee on Interstate and Foreign Commerce, United States House of Representatives. Another quotation reads as follows:

A bandwagon effect has resulted even in the medical and scientific community where too many have accepted the pronouncements (against smoking) of dedicated zealots, lacking the time to examine the scientific basis, or lack of it, for such pronouncements.

The following quotation from the 1972 annual report of Philip Morris (Australia) Limited provides another example:

During the year, the Commonwealth and several State governments passed new laws relating to the sale of cigarettes. In addition, the Commonwealth Government intends to provide funds to a Commonwealth–State committee to finance a three-year anti-smoking campaign. The new Commonwealth law requires the addition of a government health notice at the conclusion of all broadcast commercials. The regulations introduced by the States to [sic] prohibit the sale by retailers of cigarettes if the packaging does not carry specified printed
health notices. These new restraints derive from the widely published 
assertion, which is unsupported by valid experimental or clinical 
evidence, that cigarette smoking is a direct cause of certain illnesses.

Your Directors, in common with the cigarette industry around the 
world, have continuously evaluated all the evidence which has been 
put forward from time to time in an attempt to support this assertion. 
They remain convinced that the case sought to be made against 
smoking is not proved; that there are major and obvious faults in the 
arguments and statistics put forward by the proponents of the anti-
smoking thesis.

The above extract was reported in an editorial in the Medical Journal 
of Australia on 3 February 1973. In the words of the editorial:

These bland statements are made in flat (almost dead-pan) contradiction 
of the enormous mass of carefully assessed and freely available 
evidence of the harmful effects of cigarette smoking on health. 
Much of it is consolidated in the two reports of the Royal College of 
Physicians of London, the 1971 and 1972 reports of the United States 
Surgeon-General, and the reports of the First (1967) and Second (1971) 
World Conferences on Smoking and Health.

It seems that the cigarette companies now recognise that they have 
lost this battle. Evidence of this is provided by a more recent report 
from Philip Morris to the Czech Republic where this firm has about 
80 per cent of the cigarette market. According to the Guardian Weekly: 
‘The report found that the economy received a number of benefits 
from smoking. There was income from excise duty and health cost 
savings due to early mortality.’3 It was pointed out that, in 1999, the 
Czech Government saved up to the equivalent of US$32 million on 
health care and pensions for the elderly, thanks to premature deaths 
from cigarettes. The total benefits outweighed the costs of health 
care for sick smokers and loss of income tax from deceased workers. 
The net benefit to the government from the smoking population was 
calculated at US$143.5 million.

The first decade and a half of the 21st century has seen the introduction of regulations banning smoking in enclosed spaces and public places in many countries across the world, led by Bhutan and Ireland. In Bhutan it is illegal to sell tobacco. Recently, cities in China, including Beijing, have introduced restrictions on smoking in public places.

There has been a significant decline in the number of people who smoke in most Western countries. In Australia, the proportion of men and women who smoked in 1976 was 43 per cent and 33 per cent respectively. In 2014–15, it was 16.9 per cent and 12.1 per cent.

Although the psychological effect of nicotine is less dramatic than drugs like heroin and cocaine, its addictive power is just as great, if not greater. Typical withdrawal symptoms include a craving for nicotine, headaches, irritability, anxiety, sleep disturbances, hunger, difficulty concentrating and a lowered heart rate and blood pressure. Most symptoms peak in the first day or two and then lessen, although the craving for a cigarette may persist for months.

In the United Kingdom, two-thirds of smokers want to give up, and about half of these try to do so every year. Only about 5 per cent of these are not smoking a year later. In Australia, 73 per cent of smokers have tried to give it up.

Educational programs about the undesirable effects of tobacco smoking on health, therefore, seem to be only minimally effective in persuading smokers to stop. Most smokers are well aware of the damage their habit is likely to do to their health.

One approach is to try to combat the habit by administering nicotine in the form of chewing gum, lozenges or skin patches, which deliver a dose that is big enough to overcome the craving, but too small to produce a high. Nicotine alone is far less dangerous than tobacco smoke and it is much less carcinogenic, but it has some undesirable effects on the cardiovascular system. Nicotine replacement therapy is intended as a temporary measure to lessen the withdrawal symptoms, and so increasing the chances of quitting. However, 90 per cent of people who try nicotine replacement therapy take up smoking again within 12 months.
Another approach is suggested by the experience in Sweden, where 17 per cent of men are smokers. Another 19 per cent, however, ‘suck tobacco’ in the form of a product called ‘snus’, which is moist ground tobacco that is placed between the tongue and the lip, either loose or contained in a small permeable bag. The nicotine quickly reaches the bloodstream, giving rise to the pleasurable high. Snus can, therefore, be regarded as a recreational drug, and the men who use it are not trying to break their addiction to nicotine. Swedish men have by far the lowest risk of dying from smoking-related diseases in Europe — 11 per cent, compared with 25 per cent for Europe as a whole.

Ecology

The most striking ecological characteristic of the Exponential Phase of human history has been the spectacular increase in the overall scale and intensity of human activities on Earth and their impacts on the living systems of the biosphere.

Population

Advances in the medical and nutritional sciences in ecological Phase 4 have resulted in a massive increase in the human population.

At the time when farming was introduced, the total human population probably stood at around 5 million and, 12,000 years later, in 1810, it had grown to 1 billion. It took only 120 years (1810–1930) for the next billion to be added. The next billion took 30 years (1930–60); the next billion, 15 years (1960–75); the next billion, 14 years (1975–89); and the next billion, 10 years (1989–99). The next billion took slightly longer, 12 years (1999–2011), bringing the total human population to 7 billion.

Throughout much of human history, life expectancy at birth has been around 20 or 30 years. During ecological Phase 4 it has increased remarkably, and the global figure in 2013 was about 67 years. It is considerably higher than this in the developed countries. In Australia, for example, life expectancy at birth in 2013 was 79 years for males and 84 years for females.

The current global population is increasing at the rate of around 1.4 million every week.
Food sources

The industrial transition led to a new era in farming involving fundamental changes in agricultural practice, especially in cereal production. From the ecological standpoint, one of the most significant aspects of the modernisation of agricultural systems has been the change in the energetics of crop production. In the early farming societies, the energy content of food was around 15 times as much as the energy spent in collecting it. In the United States today, the energy content of food received in the home is only about one-fifth of the energy used in farming practices, transportation, preparation and wrapping. At least 90 per cent of the energy input is in the form of fossil fuels.

Another feature of the transition has been an ever-increasing application of artificial fertilisers. Phosphate and potash fertilisers are derived from natural deposits, and world resources of phosphate rock are considered to be sufficient to last for 100 to 200 years, while potash reserves may be sufficient to last about 5,000 years. Nitrogen fertilisers are now made synthetically from atmospheric nitrogen. Although there is unlikely to be any shortage of nitrogen, the methods used are energy-costly, and this may create problems in the future. The overall global use of artificial fertilisers has increased about five-fold since 1950.

Other changes have included the widespread use of synthetic pesticides to control parasites and plant diseases and the cultivation of new, high-yielding varieties of certain crops.

All in all, these changes have resulted in big increases in crop yield per unit area.

Another striking development has been the great increase in yield per hour of human labour. In the Early Farming Phase a typical farming couple produced, like hunter–gatherers, sufficient food for themselves and their families and sometimes a small surplus to contribute to the diet of non-farmers. The situation is very different in the developed regions today. In the United States in the 1970s, one farm worker produced sufficient food for 50 people. Australia is an extreme case and, in a good year, one farmer now produces enough food for 85 people, two-thirds of whom live overseas. Many farmers today, however, work for 10 or more hours each day.
The modern farmer is dependent on the work of countless other individuals involved in the design and manufacture of tractors and other machinery, in the extraction and preparation of artificial fertilisers and in transportation of materials to and from the farm.

The average person in a typical industrial society today consumes, directly and indirectly, four-fifths of a tonne of cereal grain per year; but only about 10 per cent of this is eaten in the form of grain. Most of it goes to feed animals. A small proportion of this energy eventually reaches humans as meat, eggs, milk and cheese. As a result, overall less than 20 per cent of the food energy in the grain reaches humans.

The farming systems of the exponential societies also produce a broad range of vegetables and fruits for human consumption.

In the developing regions of the world, which include most of the rice-growing areas, farming has remained labour-intensive. Nevertheless, considerable increases in yield have been achieved in some regions as a result of the so-called Green Revolution. This movement began in Mexico the 1940s and spread worldwide during the 1950s and 1960s, and it continued to have an important influence on agricultural trends during the 1970s. The Green Revolution was based on the development of high-response varieties (HRV) of wheat and rice and, to some extent, of maize and millet, as well as the expansion of irrigation and the increasing use of artificial fertilisers and pesticides.

Unfortunately, the relief provided by the Green Revolution to food shortages in developing countries, where human populations are still growing rapidly, can only be temporary. These agricultural systems have reached their limits of production. In many regions, one social outcome of the introduction of the HRV varieties has been for the rich landlords to become richer and for the landless peasants to become poorer.

Growing appreciation that widespread use of fertilisers and pesticides can eventually have undesirable ecological and health consequences has led to the organic food movement. This movement dates back to the 1940s, but it did not really take off until around 1990. Organic foods are produced with farming methods that do not use chemical fertilisers or synthetic pesticides, although organic pesticides are used. Industrial solvents and chemical food additives are not used in the processing of organic foods.
The worldwide market for organic foods has grown rapidly since 2000. Many countries are establishing formal, government-regulated certification of organic food.

Scientific advances in genetics and molecular biology have recently led to the rapid development of the new field of genetic engineering, involving the artificial incorporation of genetic material (DNA) from one form of life into the genetic apparatus of another. This approach has an enormous number of applications, including the creation of food plants that are resistant to insect pests or to certain herbicides. In the latter case, the herbicides can be used freely for controlling weeds without fear of damaging the crop in question. Genetic engineering has already resulted in the creation of countless biologically novel forms of plants, bacteria, viruses and, more recently, animals. Most genetic modification of foods has, however, focused on crops in high demand such as soybean, corn, canola, and cotton seed oil.

There are strong differences of opinion about the wisdom and morality of genetic engineering and the consumption of genetically modified foods. One author writes: ‘agricultural biotechnology is going to be one of the great disasters of corporate capital history’,4 while another takes the view that genetic engineering will, through its potential to increase yields, provide ‘a much needed boost in the struggle to feed the world’s growing population’.5

Land degradation

The production of food for over 7 billion people is putting immense pressures on the food-producing ecosystems of planet Earth.

Between 1961 and 2009, agricultural production expanded 150 per cent, due mainly to a significant increase in the yields of major crops. In many places, however, the better yields have been associated with land degradation, the main causes of which are soil erosion, loss of organic matter in the soil, disruption of natural nutrient cycles, soil salinity and various combinations of these forms of soil ill health.

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4 See New Scientist, 6 Jun. 1998, p. 3.
The United Nations’ Food and Agricultural Organization (FAO) warns that the world’s agricultural systems face the risk of progressive breakdown of their productive capacity as a result of excessive population pressure and unsatisfactory farming practices. According to the FAO, a quarter of agricultural land is already highly degraded. Another 8 per cent is moderately degraded and 36 per cent is classed as stable or slightly degraded; 10 per cent is described as ‘improving’. The worst affected areas are along the west coast of the Americas, across the Mediterranean region of southern Europe and North Africa, the Sahel and the Horn of Africa, and throughout Asia. It is feared that these agricultural systems may not be able to satisfy human demands by 2050.

Climate change is expected to have a major effect on the world’s food production, although there is much uncertainty about the extent and nature of these effects.

Water

Seventy per cent of water used by humans globally is used for agriculture. The proportion is much higher in many developing regions, and lower in the affluent countries where much water is used in industrial processes.

Severe water shortages now affect at least 700 million people across the globe and the number is expected to increase with predicted climate change. According to one estimate, more than half the world’s population will be facing water shortage by 2025.

Loss of biodiversity

The present rate of extinction of living organisms is exceptionally high, due to the activities of humankind. According to one estimate, species are becoming extinct a thousand times faster than was the case in the late Pleistocene period (126,000–11,700 years ago), when the extinction rate was well above the average for geological time as a whole.
Some authorities believe that about a quarter or more of living organisms on Earth, excluding bacteria, archaea and viruses, will be extinct by 2025. Nearly 9,000 trees, representing about 10 per cent of tree species known to science, are threatened with extinction. Over 34,000 species of plants are on the verge of extinction.

The main cause of this loss of biodiversity is habitat destruction through various activities of humankind, including farming, logging, fishing and the construction of roads and buildings.

**Deforestation**

Progressive deforestation has been taking place in many parts of the world for centuries. Around 900 AD, 80 per cent of central Europe was covered with forest, but only 25 per cent in 1900. These forests reached their minimum at about the time of the First World War.

Globally, deforestation has increased especially rapidly over the past 60–70 years. Today, far more trees are destroyed every year than are planted.

Most of North Africa and the Middle East, as well as a great deal of continental Asia, Central America and the Andean regions of South America are now virtually treeless. Problems associated with deforestation are also looming large in parts of Central Africa and on the Indian subcontinent.

More than half of the world’s tropical rainforests have been destroyed and the rate of destruction is accelerating. It has been estimated that tropical forest, which accounts for about 70 per cent of forest productivity in the world, is being destroyed at an annual rate of 4.1 million hectares in South America, 2.2 million hectares in Asia and 1.3 million hectares in Africa, giving a total of 7.4 million hectares per year. Some authors believe that the rate of decline is much greater than this. More than 20 per cent of the Amazon rainforest has already been destroyed. In 2004, the worst year on record, 27,000 square kilometres of this forest were destroyed and, recently, trees were being lost at the rate of 2,000 a minute.

If deforestation continues at current rates, scientists estimate nearly 80–90 per cent of tropical rainforest ecosystems will be destroyed by the year 2020.
Deforestation makes a major contribution to climate change. This is partly because healthy forests absorb a significant amount of the carbon dioxide emissions coming from human civilisation. The destruction of forests also results in the release of carbon into the atmosphere. Carbon emitted from this source now accounts for 12–17 per cent of all emissions resulting from human activities. This is more carbon dioxide than is given off by all cars, trucks, planes, trains and ships across the world.

Furthermore, deforestation is resulting in big losses in biodiversity, it is interfering with the water cycle and it is a major cause of soil erosion.

**Industrialisation and technometabolism**

The Exponential Phase of human existence has seen a massive surge in the intensity of technometabolism in human populations, with far-reaching ecological consequences. The overall pattern is depicted in Figure 5.1.

![Figure 5.1 Flows of materials and energy in the modern world](Source: Stephen Boyden)
Technometabolic inputs

Energy use is an important measure for a number of reasons. The rate of use of energy is probably the best single indicator of the overall intensity of human activity on the planet, since everything that we do involves a throughput of energy, although its impact will, of course, depend a great deal on the particular use to which the energy is put. It will also depend on the source of the energy, since some energy sources have by-products that have impacts on biological systems. These by-products include carbon dioxide and the oxides of sulphur and nitrogen from fossil fuels as well as the radioactive by-products from nuclear power plants.

The human species as a whole is now using about 20,000 times as much energy every day as was the case when farming began (Box 5.1). This is equivalent to the difference in weight between a small apple and a couple of tonnes of bricks. Well over 90 per cent of this increase has occurred in the past 100 years (Figure 5.2).

Box 5.1 Faster! Faster! Faster!: Energy use by humankind

The following analogy brings home the massive scale and recent intensification of human activities on Earth:

Let us suppose that farming began 12 hours ago (rather than 12,000 years ago) and that, at that time, humans jumped into a vehicle they had invented. The speed of this vehicle is proportional to the total amount of energy used each day by humankind. Energy use is a reasonable indicator of the scale and intensity of human activities on our planet.

The vehicle set off at a speed of one kilometre per hour 12 hours ago.

Four hours ago, it picked up speed and was travelling at 30 km/hr.

One hour ago it was going at 100 km/hr.

Fifteen minutes ago at 350 km/hr.

Six minutes ago at 1,000 km/hr.

Three minutes ago at 3,000 km/hr.

It is now traveling at around 20,000 km/hr.

Visibility is not good — and we, the passengers, don’t have a clear view of where we are going. But among us there are some scientists who have made a study of the environment, and they are warning that we are heading for a precipice. They are shouting out to us to slam on the brakes and change direction.

But most of us, especially those in charge, are hell-bent on making our vehicle go faster than ever.

Source: Stephen Boydlen
The main sources of extrasomatic energy throughout the industrial phase of society have been fossil fuels, although the relative contributions of coal, oil and natural gas have changed over the past 60 years. In some countries, nuclear power now makes a significant contribution to the generation of electricity.

![Energy use by the human species](Image)

**Figure 5.2 Energy use by the human species**  
*Source: Stephen Boyden*

Hydroelectricity, unlike fossil fuels and nuclear power, does not produce undesirable by-products, and it makes a significant contribution to the available power in regions where the topography allows it. Use of other clean, non-polluting energy sources, such as wind and solar power, are on the increase but, so far, they contribute only a small fraction of the total energy budget.

Other technometabolic inputs into human societies today include a vast range of materials used in the construction of buildings and roads and for the manufacture of machines and utensils as well as electronic devices. To take just one example, the per capita consumption of iron in Australia today, excluding the iron in manufactured goods imported from overseas, is around 1.3 kilograms per day. In Shakespeare’s time it was probably about one gram per day.
Technometabolic outputs: Carbon dioxide and climate change

If it were not for certain gases occurring naturally in the atmosphere, the world’s average temperature would be 33°C colder than it is. That is, it would be around −18°C instead of 15°C.

This is because these gases trap some of the infrared radiation that escapes from the Earth’s surface. This blanketing effect results in the lower layers of the atmosphere being warmer, and the upper layers colder, than would be the case if these gases were not there. This phenomenon is known as the natural greenhouse effect.

Water vapour is responsible for about 80 per cent of the natural greenhouse effect. The remainder is due to carbon dioxide, methane, and a few other minor gases.

Carbon dioxide (CO₂) is responsible for about 15 per cent of the natural greenhouse effect. This is to say that were it not for the CO₂ in the atmosphere, the Earth’s average temperature would be 5°C cooler than it is.

For the first 200,000 years of the history of modern humans (Homo sapiens), the mixture of these natural greenhouse gases was relatively constant. During the past 200 years, however, there has been an increase in the CO₂ concentration in the atmosphere resulting from human activities — from 292 parts per million to 400 parts per million in 2016. This increase in atmospheric CO₂ is mainly the result of two sets of human activities: (1) deforestation, and (2) the combustion of fossil fuels as a source of energy for driving machines and providing heat.

The amount of carbon dioxide emitted by the human population today is around 10,000 times greater than it was when farming began some 450 generations ago, and over 90 per cent of this increase has occurred over the past 100 years (Figure 5.3). It is predicted that the concentration of carbon dioxide in the atmosphere will reach double the pre-industrial level by 2050.
As a consequence of this increase in atmospheric CO$_2$, the Earth’s average surface temperature has increased by about 0.8°C, with about two-thirds of the increase in temperature occurring since 1980. This is known as the enhanced greenhouse effect.

If all populations around the world had the same intensity of technometabolism as the developed countries, the increase in CO$_2$ emissions since the time that farming began would be around 50,000 fold.

From these facts, it would seem very likely that the continuing anthropogenic increase in the concentration of CO$_2$ in the atmosphere will result in a significant increase in global temperature. If no action is taken, the consequences for humanity will be very serious.

Because of the complexity of the carbon cycle, however, there are uncertainties about the precise effect of increasing CO$_2$ in the atmosphere on global temperature. For example, it cannot be assumed that doubling the CO$_2$ concentration in the atmosphere will simply double the contribution of this gas to global warming; that is from around 5°C to 10°C — an extra 5°C.

Mathematical models have been designed to predict the likely increase in temperature due to increasing concentrations of carbon dioxide. Because of the uncertainties in the system, these models come up with different results that range from a further increase in the 21st century of 1.1°C to an increase of 6.4°C.

There are also differences of opinion within the scientific community about the relative contributions of fossil fuel use and deforestation to the increase in CO$_2$ in the atmosphere over the past 250 years. One view
holds that most of the rise in atmospheric CO₂ since 1750 has been due to the destruction of the capacity of forests and soils to take up CO₂ from the atmosphere rather than the use of fossil fuels.

As in all reform movements, there is a predictable backlash from counter-reformers. In the case of climate change, the counter-reformers are commonly referred to as climate change deniers. The main disputed issues relate to the causes of the increase in average global temperature, whether humankind is responsible for it, and what will be the likely consequences of global warming.

Here are a couple of typical quotations from two of the most vociferous climate change deniers of our time:

I am convinced that policies meant to reduce carbon dioxide-induced global warming will be destructive The right response to the non-problem is to have the courage to do nothing … Climate change is a non-problem. Even if the higher estimates of global sensitivity were correct, there is no hurry to take any action.

— Lord Monkton

Man-made climate change has become one of the most dangerous arguments aimed at distorting human efforts and public policies in the whole world …

Climate change is caused not by human behaviour but by various exogenous and endogenous natural processes (such as fluctuating solar activity).

— Václav Klaus, former president of the Czech Republic

Klaus describes concern about climate change as a ‘new wave of dangerous indoctrination of the whole world’ and says that ‘global-warming alarmism is challenging our freedom’.

However, 97–98 per cent of the most published climate researchers believe humans are causing global warming, and the finding that the average global temperature has increased in recent decades as a result of human activities has been endorsed by the academies of science in all the major industrialised countries.

Other greenhouse gases

Other greenhouse gases are on the increase in the atmosphere as the result of human activities. The concentration of methane has increased 2.5 times since the beginning of the industrial era. Although it is in much smaller quantities than carbon dioxide, it is 21 times as effective per molecule and this gas now contributes 20 per cent of the enhanced greenhouse effect. It is estimated that 64 per cent of the methane emitted into the atmosphere today is the result of human activities. Of these human-induced emissions, 33 per cent are the result of the use of fossil fuels, 27 per cent come from fermentation in gastrointestinal tracts of cattle and some other farm animals, and 16 per cent from the decomposition of organic matter in land fill.

Other gases contributing to the enhanced greenhouse effect are CFCs (chlorofluorocarbons, see below), ozone and nitrous oxide.

A recent development

In December 2015, the United Nations held a conference on climate change in Paris. The conference, which was attended by representatives of 195 countries, agreed to set a goal of limiting global warming to less than 2°C higher than pre-industrial levels. The agreement calls for zero net anthropocentric greenhouse gas emissions to be reached during the second half of the 21st century. Furthermore, the parties agreed to ‘pursue efforts to’ limit the temperature increase to 1.5°C.

This conference is indeed a most important step forward, although it remains to be seen to what extent the countries across the world comply with its recommendations.

CFCs

There has been a steady accumulation over recent years of chlorofluorocarbons (CFCs), methyl bromide and halons in the atmosphere. CFCs are synthesised chemical compounds used in refrigerators, and methyl bromide is a biocide used for the control of insect pests in the soil and in grain products. The main use of halons is in fire extinguishers.

In 1974, Frank Rowland and Mario Molina suggested that these compounds might, on reaching the stratosphere, destroy the ozone that protects the surface of the Earth from ultraviolet (UV) radiation.
from the Sun. This would result in increasing damage to terrestrial organisms, with serious consequences for the natural environment and for humankind. The shorter wavelength UV-B rays are especially harmful. It is predicted that the yields of soybeans, peas and beans will decrease by a quarter if UV-B radiation increases by 25 per cent. Increase in UV radiation is also likely to destroy plankton at the surface layers of the oceans. Because phytoplankton are at the base of the oceanic food chain, this change will have a devastating impact on populations of fish and other animal life in the sea.

Eventually, evidence was forthcoming that the ozone layer was indeed thinning. This evidence was promptly disputed by representatives of the aerosol and halocarbon industries. For instance, the chair of the board of DuPont was quoted as saying that ozone depletion theory is ‘a science fiction tale … a load of rubbish … utter nonsense’. 8

In this case, however, the counter-reform backlash was relatively short-lived. The processes of cultural reform are now well advanced and, as a result of international agreements, there has been a major reduction in the release of CFCs and related compounds into the atmosphere, and it is now hoped that the ozone layer will be back to normal by around 2065.

Persistent organic pollutants (POPs)

In *Silent Spring*, Rachel Carson drew attention to the insidious and destructive ecological impacts of DDT, which is one of a group of halogenated hydrocarbons that are used as pesticides and in various technological processes and which have become known as persistent organic pollutants (POPs). POPs accumulate in the internal organs of living creatures and are believed to be responsible for increasing and widespread infertility in wild animals, and probably also humans. They are also suspected of contributing to the increase in breast cancer in women and to reduced sperm counts in men. POPs are persistent in the natural environment and have been found in the organs of animals in areas that are far away from where they were originally released, such as the Arctic and the Antarctic.

Some authorities consider pollution of the environment with POPs as being as serious a problem for life on Earth as the enhanced greenhouse effect or the thinning of the ozone layer.

A strong counter-reform backlash occurred in response to Carson’s claims. To take just one example, the president of a large chemical corporation described her as ‘a fanatic defender of the cult of the balance of nature’.9

Local air pollution

Local air pollution with hydrocarbons is an important ecological issue in many urban areas, especially in Asia — Beijing is a notorious example. The main cause is the combustion of fossil fuels in power stations, factories and motor vehicles.

Particles of less than 10 micrometres (PM10s) and those less than 2.5 micrometre (PM2.5s) are especially important, being small enough to penetrate deeply into the lungs. These pollutants can cause respiratory disease in humans, including pneumonia, bronchitis and asthma.

Technoaddiction

In the history of civilisation it has frequently been the case that new techniques have been introduced simply for curiosity, or sometimes because they have benefited a particular individual or group within society. But, with the passing of time, societies have organised themselves around the new techniques and their populations have become progressively more and more dependent on new technologies for the satisfaction of basic needs. Eventually, a state of complete dependence is reached.

The dependence of the populations of ecological Phase 4 societies on fossil fuels is an obvious and serious example. Others include our dependence on electricity and, quite recently, on computer technology.

This insidious form of addiction passes largely unnoticed, although it is often of immense economic and ecological significance.

From the ecological standpoint, it is significant that in the modern cultural setting the following basic behaviours generally use up much more energy and create much more pollution than they did in the past: seeking in-group approval, seeking to conform, seeking attention, seeking novelty, seeking excitement, seeking variety, seeking comfort, visiting relatives, being selfish, being greedy and being generous.

**Ecological Phase 4 will soon come to an end**

We don’t have to be ecologists to appreciate that the living systems of our planet that support us will not be able to tolerate this relentless maltreatment from the human species ad infinitum. At present, anthropogenic climate change is the most urgent threat. But there are many other critical issues that require urgent attention if civilisation is to survive (Box 5.2). If present trends continue unabated, the collapse of civilisation is inevitable. The days of ecological Phase 4 are numbered.

The most disconcerting feature of the present situation is the fact that the prevailing cultures of the world are blissfully unaware of these ecological realities. They incorporate powerful delusions that are incompatible with the achievement of ecological sustainability and therefore the survival of civilisation. They have lost sight of our total dependence on the life processes that underpin our existence, and they have no grasp of the magnitude and seriousness of current human impacts on the ecosystems of our planet.
Box 5.2 Some serious signs of cultural maladaptation in the modern world

- A steady and continuing increase in the concentration in the atmosphere of the greenhouse gas carbon dioxide, from the pre-industrial level of 280 parts per million by volume to 400 parts per million in 2013. This is due to the use of fossil fuels as a source of energy by humankind and to widespread deforestation. There is strong evidence that this change is leading to increased temperatures across the globe and to other climatic disturbances. If allowed to continue unabated it could lead to a massive drop in the global population later in this century.

- Destruction of 80 per cent of the world’s original forests. At present, trees are felled in the Amazonian forests at the rate of 2,000 a minute. Deforestation is contributing to climate change and is resulting in great loss of biodiversity.

- Severe land degradation (due to loss of organic matter, disruption of natural nutrient cycles, soil erosion and salinisation) resulting from deforestation and unsatisfactory farming practices. According to the FAO, a quarter of farming land is highly degraded. Another 8 per cent is moderately degraded and 36 per cent is classed as stable or slightly degraded. Ten per cent is described as ‘improving’.

- Worldwide loss of biodiversity on land and in the oceans. According to some estimates, 25 per cent of all mammal species could be extinct in 20 years’ time.

- Persistent organic pollutants (POPs) are now found in the tissues of humans and other animals all over the world. POPs are synthetic compounds used as pesticides and for other purposes. They can cause ill health or death and they interfere with reproductive processes.

- Acidification of the oceans resulting from an increased uptake of carbon dioxide from the atmosphere.

- Thousands of weapons of mass destruction stored in the arsenals of the world — many times more than necessary to bring an end to the human species.

- Violent conflicts across the world between people holding different beliefs about the supernatural.

- Extreme disparities in health and material wealth among human populations (this was not the case for the first 190,000 years of human existence).

Source: Stephen Boyden