Introduction

There is no denying that the world is facing ecological changes that we ourselves have brought about, such as climate change, that are of great detriment to our own species as well as to others. And it must also be admitted that the longer we wait before wholeheartedly dealing with the situation, the worse it will be for us and our children. But where should we concentrate our efforts? What is the appropriate general strategy? To be able to answer these questions, late though they be, we should first consider more closely the nature of our ecologically disruptive behaviour. What exactly does it consist in; and how long has it been going on?

In this book answers are provided to these questions. As regards how long we have been behaving in an ecologically disruptive way, it will be found that we have been doing so as long as we have existed. And, as is suggested by this, what this behaviour consists in is intimately related to our nature as a species. To understand our negative impact on the environment we have to understand ourselves as a species.

For purely intellectual reasons we have since the time of Darwin been in need of an explanation of the development of *Homo sapiens* as distinct from other species. What has been lacking is a theory in which the *causal mechanism* behind our development is laid bare. For such an explanation to be acceptable, the theory must of course be in keeping with the results of science – an added bonus being that it also be in keeping with common sense. In this book I shall present a theory of *Homo sapiens*' development that attempts to meet these criteria, a theory based on what I call *the vicious circle principle*.

Darwin's theory of natural selection provides this sort of explanation of the development of *life*, the primary cause lying behind this development being "the mutability of species," i.e. the tendency for species to succeed one another through the mutation of their chromosomal structures or karyotypes. In the explanation of humankind's development to be attempted here, I shall, like Darwin, also suggest that development is primarily the result of one key cause, which in Darwin's terms could be called "the mutability of technology," i.e. humans' tendency to *innovate*.

So where Darwin's theory of natural selection is based on the principle of evolution, the theory of *Homo sapiens'* development presented here, which presupposes Darwin's theory and involves similar reasoning, is based on the vicious circle principle. In fact, the present theory may be seen as an extension of Darwin's theory in such a way as to explain the development of humankind.

Where the principle of evolution came to constitute the core of biology, which is presupposed by all the life sciences, the vicious circle principle is intended to constitute the core of *human ecology*, which is presupposed by all the *social* sciences. So the vicious circle principle is here being advanced as the fundamental principle of the social sciences, against the background of which social change is to be understood.

From the above it may be seen that our species is special in being the only species to have constantly developed technology. And, as we shall see, it is just this technological innovativeness that is responsible for our present ecological predicament. In sum, we have simply been too smart for our own good.

1

Scientific ground rules

Principles of physics, chemistry and biology

Any attempt to explain a particular phenomenon – in the present case the development of humankind – must rest on certain *principles*. These are the basic presuppositions underlying the explanation; and they must be accepted as correct by those to whom the explanation is directed. The presuppositions on which the theory to be presented here are based are central principles of modern science,[1] each of which states something about the nature of reality as it is assumed to be in science and, thus, as it ought to be assumed to be generally. The relevant sciences include physics, chemistry, biology and ecology – as well as human ecology, the core of which is here suggested to be the vicious circle principle. In what follows I shall present the relevant principles explicitly, marking them with Roman numerals, it generally being the case that each principle presupposes others with a smaller number.

The most important principle of *physics* is:

I. The principle of the conservation of energy

This principle was first put forward by R. J. Mayer in 1842. It is also known as the first law of thermodynamics. It states that:

Quantity of energy is constant.

Thus energy can be neither created nor destroyed, but only *transformed*.

Another physical principle of consequence to the development of humankind is:

II. The principle of the equivalence of mass and energy

This principle has been expressed in the form of the equation:

$$E = mc^2$$

– *energy equals mass times the speed of light squared*. The aspect of this principle – due to Henri Poincaré and others during the first decade of the 1900s – that is of relevance for our investigation is that *matter is a form of energy*.

III. The principle of the conservation of matter

This principle underlies the science of *chemistry*, and was first advanced by Antoine Laurent Lavoisier in 1789. It states that:

Quantity of matter is constant.

In other words, *energy cannot be transformed from a material form to a non-material form or vice versa*. Matter can change from being in a state of high potential energy to being in one of low potential energy, or the other way round, but the total amount of matter in both states is the same. Though this principle does not apply to subatomic energy transformations, it is considered to apply to all other forms of energy change, thus generally making matter a form of energy which is itself like energy in that it can neither come into nor go out of existence.

The fundamental way in which energy is transformed is captured by:

IV. The entropy principle

This principle, first advanced by Sadi Carnot in 1824, is also known as the second law of thermodynamics. It states that:

Energy tends to dissipate.

Over ***time****, energy tends to spread in* ***space***. This principle may also be expressed in terms of systems, namely: *systems tend towards disorder*; or, *the amount of entropy in a system tends to increase*. It can also be expressed as: *the quality of the energy in a system tends to decline*; or, *the degree of 'organisation' of matter in a system will tend to decrease*; or, *the free or potential energy in a system will tend to become bound or kinetic energy*.

While the principle of the conservation of energy tells us that energy never really disappears, the entropy principle tells us that it constantly spreads out in space, which, from the point of view of its availability for human use, is equivalent to its disappearing. Energy from the sun counteracts the entropy principle in the case of life, such that the dissipation incumbent upon the principle is not evident for periods of time in the case of living organisms. But for this to be possible the entropy of the larger system – including the sun – in which the biological organism exists must itself increase.[2]

Here we might consider the relation between the entropy principle and human resource use. The entropy principle implies that nothing can be recycled indefinitely, so that a sustainable human society, should one ever come about, will have to do without non-renewable resources, including many stones. In this regard we must keep in mind the difference between applying the entropy principle solely to a *particular used entity*, applying it to the *larger system* in which the entity is used and which includes it, and applying it to the *total resources* of the same sort as the entity. At least in the second and third cases, and often or usually in the first, in the end there will be an increase in entropy. As regards the particular entity used, there may on occasion be a *decrease* in entropy vis-à-vis the material of which it is composed even when its life-cycle is complete (e.g. in the case of a discarded aluminium can), though such a decrease will have no practical implications, and only occurs in the case of certain sorts of entity under certain conditions. Before pursuing this topic further, however, we should distinguish some basic types of resource.

Types of resource

Some resources may be termed *potentially permanent*. These include air (or oxygen), which constitutes a potentially permanent '*stock*,' and fresh water and solar radiation, which constitute potentially permanent *flows*. Air and water (matter) naturally move in *cycles*, while solar radiation (energy), after being used, is released as heat into space. The presence of all three (including water generally rather than just fresh water – salt water being a stock rather than a flow) of these resources is a precondition for the existence of virtually all life and thus all biotic material. What makes them only *potentially* permanent is their availability. Thus, air and fresh water may become less available by being polluted; or the availability of solar radiation could be lessened e.g. by an increase in cloud cover. In other words, these resources *are* permanent in a natural setting, but the more this setting is interfered with by humans, the less accessible they are both to us and to other species. Note that all non-nuclear energy used by humans stems from solar radiation, either directly, as in the case of solar panels, or indirectly, as in the case of virtually all other forms of energy provision.

Non-permanent resources include those which are *renewable*, i.e. semi-biotic materials such as soil, the presence of which is necessary for all non-marine life, and biotic materials such as forests and food; and those which are *not* renewable, such as metals, fossil fuels and species. While the *atoms* of metals and other chemical elements are permanent, the ability to separate the atoms from one another makes the elements themselves susceptible to the entropy principle and thus non-renewable, as will be seen below. And where biotic materials generally can renew themselves, once a *species* disappears it cannot be regenerated. In the case of soil, in order that it constantly be renewed, it cannot be eroded or leached of nutrients; and as regards biotic material, the conditions necessary for its reproduction cannot be undermined. The *sustainable* use of renewable resources implies that they are given time and space to regenerate.

The use of any non-permanent resource will mean its depletion, i.e. an increase in its entropy. If the resource is renewable, and is being used sustainably, then this depletion will only be temporary. If the resource is non-renewable, then this entropy increase will be permanent, and we can thus call the use of such resources *non-sustainable* (or unsustainable).

As used by humans, direct solar radiation is in fact *not* permanent, since its acquisition or use presupposes the acquisition or use of non-renewable resources such as metals or petroleum-based plastics. Similarly such energy sources as the tides, ocean thermal energy, and the undoubtedly unattainable nuclear fusion must all be considered non-permanent. Nor is hydroelectric power or geothermal energy for electric power generation a permanent resource. All dammed reservoirs eventually fill with silt, and all geothermal electric power facilities decline in their ability to supply energy.

Of the non-renewable resources, the potentially permanent resources of air and water are *reusable*, while solar radiation is not. Metals, paper and plastics, on the other hand, are *recyclable*, while e.g. fossil fuels and animal species are not. Any particular recyclable resource will increase in entropy with each recycling until it cannot be recycled any more or until recycling it isn't worth the effort.

Apart from plant and animal species (as well as genera, families, orders and so on), virtually all non-renewable resources are minerals, the term *mineral* correctly suggesting that such substances are obtained by *mining*. Minerals may be organic or inorganic, organic minerals *having been* biological – the primary instance being fossil fuels, while inorganic minerals include the chemical elements and thus metals, as well as stones.

In economic-thermodynamic terms, we tap *reserves* of various forms of low entropy available to us when we mine, while in using renewable resources we tap the *flow* of low entropy to be found in living beings (biota). Both fossil fuels and biotic resources constitute sources of low entropy in the form of concentrated solar energy.[3] The exploitation of renewable resources typically involves the *harvesting* of living beings, such as animals, vegetable foods, and trees, while the exploitation of potentially permanent (or quasi-permanent) resources involves the *harnessing* (for energy) of such non-living entities as wind and water. The use of a renewable resource in a way that does not allow it to renew itself essentially makes it a non-renewable resource, and eventually leads to its disappearance, the paradigm being the extinction of megafaunal species during the Palaeolithic.

Another potential form of resource – finite though renewable – pointed to by J. P. Holdren,[4] consists in the capacity of the environment to absorb the effluents and other impacts of modern technology.

Products' life-cycles

Looking at human resource use more closely, we note that the life-cycle of a product can be said to go through four basic stages (as well as certain intermediate ones, which can be assimilated to the basic ones): acquiring the resource, working it into a product, using the product, and then getting rid of the remains. The place from which the resource is acquired is its *source*; once acquired, the resource is turned into a *product*, which is then *used* and later disposed of, the place of its final disposal being its *sink*. In this context, the entropy principle says that *all* used resources will eventually end up in a sink. This implies, among other things, that quantity of waste cannot be reduced without reducing the quantity of materials used.

The principle of the conservation of matter tells us that the total quantity of matter that goes into a sink is the same as that which comes from the source, and that it is in fact the very same matter; and the principle of the conservation of energy tells us that the total amount of energy before and after using the material will also be the same. As regards renewable resources such as food and wood, we know that, as long as they are not over-exploited, their use as a whole can continue indefinitely; the constant influx of solar energy is sufficient to counter the operation of the entropy principle. As regards resources that are neither renewable nor recyclable, such as fossil fuels and animal species, their use or elimination is a one-time event: once e.g. oil has been burned its usable low entropy has been completely converted to useless high entropy. But the situation concerning *recyclable* resources is more complex.

In this regard we might consider the life-cycle of a particular recyclable product, such as a sheet of copper.[5] The *first* stage in the life-cycle of the sheet consists in the acquisition of copper ore from a mine – the *source* of the copper – and transporting it to where it can be made into a product, an operation that requires the transformation of free into bound energy through the use of machines. This means, at this stage, an increase in the *total* amount of entropy, i.e. an increase in the entropy in the larger system in which the relevant activities are taking place.

The *second* stage – the creation of a usable product in the form of a sheet of copper – may be seen as including the refining of the copper, the making of the product, and the transportation of the product to where it can be used. Here we note that the entropy of the resultant copper will have *decreased* as a result of these processes, particularly that of refining the copper: the pure copper has a greater degree of order than does the copper ore still in the ground. Following Nicholas Georgescu-Roegen, we see that this does not mean that human economic activity eludes the entropy principle however.[6] The processes of obtaining the ore, refining the copper, making the sheet, and transporting it to where it may be used, *all* require the transformation of free into bound energy, and this increase in entropy is much greater than the loss in entropy in the copper. In systems terms, the entropy principle tells us that it must be the case that more free energy or low entropy is used up in the larger system than the difference in the subsystem between the entropy of the original ore and that of the finished product.[7] As expressed by Herman Daly, the inevitable cost of arranging greater order in one part of the system (the human economy) is the creation of a more than offsetting amount of disorder elsewhere (the natural environment). And in increasing the entropy of the non-human part of the biosphere we interfere with its ability to function, since it also runs on low entropy.[8] This is a state of affairs that doesn't arise in the case of other species, in which there is no technological development.

As regards the *third* stage in the life-cycle of the copper sheet, its *use*, the entropy principle tells us that this use will increase the entropy of the copper the sheet is made of, as it wears away or is otherwise released into its surroundings. Any attempt at *recycling* will of course be part of a process in which the entropy of the copper constantly increases. Eventually the bits of copper become too spread out to be usable;[9] the free energy required to obtain them will be greater than that required to obtain copper from copper ore. Thus, as expressed by Georgescu-Roegen, "There is no free recycling just as there is no wasteless industry."

As regards the *fourth* stage, the disposal of the copper, what is left of the sheet may just end up in the dump, which would then constitute its *sink*. By this time, it would no longer be worthwhile to collect it once again for recycling, otherwise we would be mining dumps for copper (as I'm sure some poor people are doing). In any case, the free energy required to obtain copper is constantly increasing, and at some point it will no longer be worthwhile in energy and/or economic terms to continue mining it in any way.

Entropy and the economy

This state of affairs has important ramifications regarding the human economy. As made clear by Georgescu-Roegen, the economic process, like any systemic process, consists of a continuous transformation of low entropy into high entropy, the energy cost of any economic enterprise always being greater than the product, as intimated above. Economic activity neither creates nor consumes matter or energy, but only transforms low entropy into high. In the purely physical world the entropic process is automatic in the sense that it goes on by itself. The economic process, on the other hand, through its increasing order in the *social* system, *increases* the rate of entropy production in the larger biophysical system, i.e. in the *ecological* system (ecosystem), of which the social system is a part. In fact the economic system itself constitutes a biophysical system the existence of which leads to increased entropy production in the other biophysical systems with which it interacts,[10] through its producing waste at a rate greater than can be assimilated by the ecosystem. Such activity cannot continue in a sustainable society, in which energy use may not exceed the usable energy received from the sun on a year-to-year basis, which implies that waste must be neutralised at least once a year if the population is not to experience population pressure, The entropy principle also applies to the sun, which is itself a system that is constantly losing energy. But this loss is taking place so slowly that it is not taken into account with regard to the development of *Homo sapiens*. In all probability the earth will receive a flow of solar energy of sufficient intensity to counteract entropy and maintain life on this planet for another five billion years.

The existence of low entropy, or free energy, is necessary to life on earth. The nature of this life, as studied in biology and as presupposed by our investigation, is determined by:

V. The principle of evolution

This is the fundamental principle of *biology* – put forward by Charles Darwin in 1859. In its modern form it states that:

> *Life forms on earth have evolved from a common source, each surviving as a species as a result of its being karyotypically adapted to its biological and physical environment.*

One implication of the principle of evolution is that humans are animals, and constitute a part of nature just as other animals do. Accordingly, as regards the basis of our physical existence, we do not stand above other life forms, but among them. And, just as is the case with them, when the human species proves unable to adapt to its environment, it will become extinct.

Relative to other life forms, humans are an extremely recent arrival. The change in karyotype (see Glossary) resulting in the coming to be of our species occurred only about 200,000 years ago. This may be compared with other species, an extreme example being that of shellfish called *brachiopods* or *lamp* *shells*, some forms of which have remained unchanged for at least the last 500 million years, thus having existed on earth about 2500 times longer than we have.

Adapting to the environment means fitting into a system.

Physical and biological systems

A *system* in its simplest form is any group of entities amongst which there is an ongoing cause-and-effect relationship. The existence of the form of the relationship over time is what makes the system a system and not simply a one-time event. Thus a raindrop falling on a stone is not a system, but a constant dripping of water on one part of the stone is a system.

As implied above, what more is required of a state of affairs in order for it to be considered a system is that its constituents *interact*. Given the physical notion of cause, however, *any* continuing causal relation constitutes a system. This is thanks to Newton's third law – another principle, already expressed by Aristotle – which states that physical cause and effect are equal and opposite, or, to every physical *action* there corresponds and equal and opposite physical *reaction*.

This interaction may be more or less noticeable in different cases. A single stone constitutes a system, since its constituents interact, holding it together. (In fact, from one point of view, any situation that does not evince total entropy constitutes a system.) But their interaction is not obvious, in that it does not involve change. (In what follows the term *system* will be used only in referring to such systems as involve internal change.) In some systems the cause may be obvious while the effect is hidden, or vice versa. In the case of water dripping on a stone, the collision of the water drops with the stone causes the water molecules to disperse rapidly, while the stone molecules disperse much more slowly, eventually giving rise to a hollow in the stone. The effect of the stone on the water drops is more noticeable than the effect of the water drops on the stone, though they are physically equal.

The *solar system* constitutes a relatively simple system, where the gravitational force (cause) exerted by the sun on the planets is exactly equal and opposite to the force exerted by the planets on the sun. The effect of the sun on the planets appears to be larger however. One thinks of the planets' orbits as resulting from their attraction to the sun, when they are just as much a result of the sun's attraction to them.

The internal *spatio-temporal* relations of a system constitute its *structure*, and the interaction of its internal and external *causal* relations determine how it is *organised*, i.e. the nature of its *internal* causal relations (and, in turn, its structure).