1

Part III: Overview of the Sciences

1 Life, the Universe and Everything

The Big Picture

The universe has an amazing structure in space. There is a remarkable hierarchy of ascending levels of organisation. It is one of the most remarkable things about it, and also a major problem facing all attempts to explain its origin in terms of evolutionary naturalism. It is actually, of course, very difficult to map the very largest scale structure from the Earth, but it appears that the galaxies are clustered together and then wrapped around huge voids in a foam-like or 'tangled cobweb' structure.

Galaxies are massive systems of stars. Our own star, the Sun, belongs to the Milky Way galaxy. This is a spiral galaxy with a diameter of over 900 quadrillion kilometres and containing over 100 billion stars. Such numbers are far too large to comprehend. If we were to name those stars at one per second it would take us over 5000 years to complete the task! There are probably another ten billion galaxies beside the Milky Way, so the total number of stars is truly 'astronomical'.

Galaxies always appear to occur in groups of associated galaxies called *galaxy clusters*. The Milky Way belongs to a cluster called the Local Group which contains some 30 members. This is quite small as the average cluster contains 100-200 members and the largest clusters contain several thousand. The Virgo Cluster contains some 2500 galaxies and the Coma Cluster some 10 000.

Galaxy clusters are then themselves located in *superclusters*. Our Local Group is part of the Local Supercluster which contains about 100 galaxy clusters. These superclusters then form the 'tangled cobweb' mentioned above.

Almost all celestial bodies show some degree of axial rotation. For the Earth this gives essential gyroscopic stability (*cf.* a spinning top or revolving bicycle wheels). If the Earth was not rotating it would tumble through space, the poles would alter position continuously and there would be no regular seasons. Galaxies, clusters and superclusters also appear to rotate. This phenomenon is difficult to explain in terms of 'big bang' theory, i.e. how could the outward radial motion of the big bang give rise to rotation in vast orbits around different centres throughout the universe?[1] There is even some evidence that may indicate that the universe as a whole is rotating. If confirmed this would be very difficult to explain in terms of big bang theory.[2]

Why is such a huge universe needed? Is the Earth really totally insignificant? Our ignorance remains vast, but there are already indications that, however strange it seems, such a vast universe is needed for there to be a stable planet called Earth which can be inhabited by human beings.[3] Indeed, one of the most significant discoveries of recent times (often discussed as the *Anthropic Principle*[4]) has been that the characteristics of the universe, of our galaxy, of the solar system, and of the Earth itself, are so finely tuned to support human life that the only reasonable explanation is that they have been *designed* with humans in mind.[5] The standard secularist reponse is to argue that there is an infinite number of universes, all with different values of the key physical constants, so there is nothing surprising in the fact that we exist in the one which has, by chance, that set of values which permits human life. The counter-response is that we have no evidence whatsoever of the existence of any other universe. The double standards involved in the argument must also be exposed. Secularists have constantly mocked Christians for believing in a 'God of the gaps' - for supposedly invoking divine intervention wherever gaps are found in human understanding of the world. But here we have secularists invoking 'Chance of the gaps' - appealing to chance occurrences wherever scientific findings have obvious design implications. In any event the fact remains that the findings of cosmology are what might be expected if the universe was created.

Coming Down to Earth

Stars are the most prominent objects in the universe, but there are actually very few near the Earth. Our nearest star (apart from the Sun) is *Proxima Centauri* which is over 40 trillion kilometres (4.3 light years) away. Only about 6000 stars can be seen with the naked eye from the earth and only about 3000 from any one place. All of these stars belong to our own galaxy, but their diversity of types and colours is breathtaking. Sadly, in most large towns 'light pollution' means that very few stars can be seen at all, and all the colour is lost. We are all the poorer for that loss of vision. Surely, Satan rejoices that so many can never behold the heavens that 'tell the glory of God' (Ps 19:1).

Stars vary enormously in size - from *white dwarfs* about the size of the Earth to *supergiants* that would include much of the solar system.

The Sun is a medium-sized yellow star.[6] It is a single star[7] of greater than average mass and luminosity[8] and somewhat variable. It has a complex solar system consisting of nine planets, maybe about 100 moons, thousands of asteroids and comets, and countless meteoroids. It is certainly *not* an 'average star'.

The Earth is the only temperate, wet planet in the solar system, and, in all probability, in the universe.

It has become increasingly clear that the size and complexity of the solar system is essential for life on Earth. The gravitational pull of the giant planets, especially the very massive Jupiter, protects the smaller planets such as the Earth from frequent collisions with comets and asteroids.

Given that we need several planets, another problem arises. The Sun and planets interact with each other in such complicated ways that the orbits of all the planets are chaotic (*i.e*. unpredictable in the long-term). Nevertheless, against all expectations, it appears that the whole system is so structured that it does remain very stable indeed.[9] Similarly, Earth's large Moon prevents gravitational tugs from the other planets destabilising the Earth's angle of tilt (which creates the regular pattern of seasons). Without the Moon, the tilt would be unpredictable leading to highly erratic variations in climate (as does happen with Mars).[10]

When all these factors are taken into account, the existence, elsewhere in the universe, of planets that could support life, seems very unlikely.

What on Earth is it?

The report on the planet was coming in. It was not encouraging:

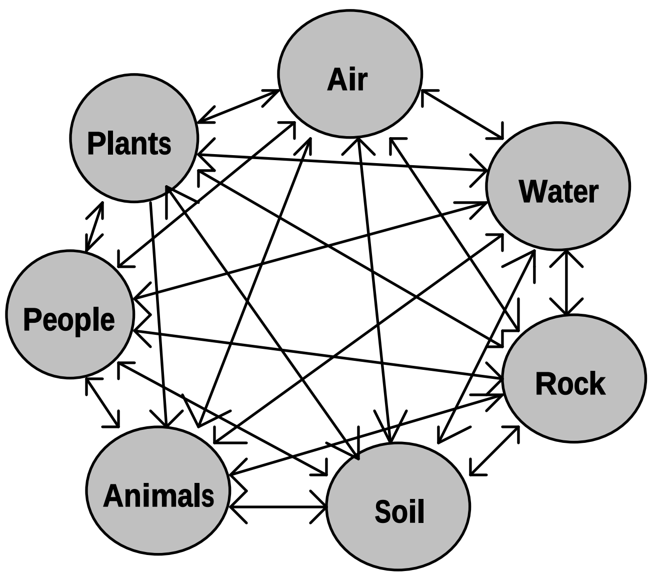
> "Typically the surface pressure is between 200 and 400 atmospheres and the temperature is 2 ^{o}C. No light reaches the surface. Across the planet run chains of vigorously active volcanoes, riven by faults and dotted with springs of superheated water at up to 400 ^{o}C. Away from the volcanoes, swarms of astonishingly diverse soft-bodied scavengers inhabit the surface mud. Around the hot springs, oases of intense bacterial productivity support rich communities of grotesque organisms."

Which planet? Earth! Surprisingly, two-thirds of our planet fits this description. Which two-thirds? The deep ocean floor. In fact we face the same puzzle as before. We occupy a very thin film over parts of the land surface (section 4 below). Why, then, does a world created for humankind contain so much deep ocean? Again it seems that it is both needed and just right. For example, it is now suggested that it is bacteria living in the sediments of the seabed that are responsible for regulating the atmosphere's oxygen content.[11] The Earth's temperate climate and climatic stability also owe much to the moderating influence of the huge ocean system.

With this setting-of-the-scene we can turn to look at the earth and its sciences in more detail.

2 Earth's Domains

Figure 1.4 Earth's Interacting Domains



Life at the Boundary

Science courses should be meaningfully related to the universe as a whole and, specifically, to the interacting domains of our planetary world (Figure 1.4). Three of these are foundational physical domains that represent the three normal states of matter: *atmosphere* (gas), *hydrosphere* (oceans, seas, and lakes etc. - liquid) and *crust* (solid). The other life (plants, animals, people) or life-related (soil) domains are largely organised around the boundaries (interfaces) which these three provide. For example, we and most other land animals live at the boundary between land and air.

Earth's Planetary Services

Each of the Earth's domains consists of a number of major *ecosystems* (or *biomes*) both natural (*e.g*. open ocean, forest, wetlands) and cultural (*e.g*. urban areas, croplands). These ecosystems carry out a variety of functions which provide both goods and services for the benefit of the world in general and for humans in particular (Table 1.3).

Table 1.3 Some of Earth's Goods and Services[12]

Goods and Services	Functions
Gases	Regulating composition of the atmosphere.
Water supply	Storing and retaining water.
Water flow	Providing and transporting water.
Raw materials	Producing lumber, fuel, fodder etc. Recycling.
Soil	Forming and maintaining soil.
Biological resources	Providing pets, agricultural and horticultural varieties, sources of medical or material products, useful genes etc.
Climate	Regulating global and local processes that determine temperature, humidity, rainfall etc.
Nutrient cycling	Acquiring, storing, processing and cycling nutrients.
Pollination	Transferring pollen and provisioning pollinators.
Food production	Producing food through hunting, gathering, farming or fishing.
Refuges	Providing habitats for transient and migratory populations.
Biological control	Regulating animal and plant populations through biological interactions (including pest control).
Disturbances	Protecting and restoring habitats subject to damage from storm, flood, fire, drought and disease etc.
Erosion control	Retaining soil within the ecosystem.
Waste treatment	Recovering nutrients and removing/neutralising pollutants.
Technological	Providing/maintaining sites of historical and archaeological interest (e.g. caves).
Social	Providing for tourism and for outdoor sporting, recreational and educational activities.
Aesthetic	Providing human habitats that are pleasant and beautiful, but also tinged with mystery (allusiveness).
Symbolic	Establishing and maintaining richly symbolic surroundings.
Confessional	Protecting/enduing features that point beyond themselves to transcendent reality.

A few of these functions are almost purely physical, but most involve physical and biological processes. Human involvement and careful management are usually desirable and some functions are characteristically human in their reference. For the systems to work effectively, a minimum level of 'infrastructure' and capital stock (trees, minerals, buildings, institutions etc.) are necessary.

God has given us a planetary home which provides, actually or potentially, all the necessary goods and services for abundant and fulfilling human life. Moreover those goods and services are provided very efficiently and at low cost.

A topical example is that of flood control. The technological solution has been dams and dykes (sea walls). These bring their own problems and the balance of costs and benefits is often disputed. Dams, for example, alter the ecology of whole regions in unpredictable ways,[13] trap fertile silt, and often induce local earth tremors.[14]

It is becoming clear that supporting and enhancing the natural controls is a better - and much cheaper - way forward. Along tropical coasts mangrove forests are far more effective than concrete at keeping out the sea.[15] Mangroves stabilise the seafloor, trap sediments and help to dissipate the energy of breaking waves by reducing the angle of the seabed's slope. They also encourage coastal fisheries by providing nutrients and sheltered spawning grounds, provide timber, and honey from the bees attracted to their flowers. Similarly, as regards river flooding, there is growing evidence that the maintenance of natural flood plains (allowing controlled flooding) works better than dykes and barriers.[16]

Human well-being is sustained and advanced when these natural services are all available *simultaneously and indefinitely*. Yet all human activity affects the ecosystems and today often does so harmfully. The cost, in far more than just economic terms, of repairing the damage, or of building technological replacements, is enormous. Indeed many of the services are literally irreplaceable. However, because many of the services are unacknowledged and unmarketed, the tendency is to ignore them, take them for granted, or at least undervalue them. Inevitably projects are constructed in which the diverse human costs far outweigh the benefits. The contribution of natural ecosystem services to human well-being must, therefore, always be included in any evaluation of project proposals.[17]

Saving the World

The better we understand the Earth's created systems and processes, the better we can manage them for the good of all. Enough is already known to indicate the enormous scope for savings in our use of basic resources. In Britain we have been shocked to learn how much drinking water is lost through leaking pipes.[18] The potential savings in other areas are at least as great. For example, the total energy wasted in lighting a room with an electric lamp by burning fossil fuel in a power station averages around 97%![19] It is technologically possible for Western economies to at least halve their use of energy and water and thereby reduce the pressure on natural systems.

Many of our practices cry out for critical scrutiny. In the Western world enormous resources are devoted to pets and ornamental plants. Caring involvement with animals and plants is a vital aspect of human well-being, but there is something fundamentally wrong with the wasteful, and often cruel[20] ways in which we provide for that involvement today. More importantly, at present yields, world food production is probably sufficient to feed a second planet. The problem facing the 1 billion hungry people is not lack of food, but lack of the money to buy it. In addition there is substantial evidence that sustainable (low-input, resource-conserving) agriculture can feed the world.[21]

Sadly, it is too often the case that we fail to question the way things are because we are members of privileged groups and the present world political-economic system works only too well for us and our children. Christian education will not be comfortable. If it would be faithful, then it will also disturb. In laying out a rich view of the world that sets out a vision of wholesome cultural development, it must also expose those sinful practices that abuse God's creation and impoverish human life.

3 Physical Sciences

Action and Order

In physics and chemistry, *physical action* is the special kind of functioning that we are studying. It is common to all physical things on their own and also when they are 'harnessed' by other realms (e.g. when they are functioning in organisms or buildings - see Part IV, Section 2). All physical things are characterised by an ability to *interact* with each other. All statements in physics and chemistry are fundamentally descriptions of how something behaves when undergoing an interaction of some kind under specified conditions. As a statement in physics, 'This thing is red' is likely to mean 'When illuminated by white light, at normal room temperatures, this thing *absorbs* light of all colours except red which is *reflected*'. Galaxies, stars, molecules, atoms, electrons, neutrinos etc. are held to exist, not because they can be seen (they cannot), but because they can be shown to occur with specific properties of interaction. For example, 'stars' are still only points of light in even the most powerful telescopes. We are confident that they are flaming balls of gases, because analysis of their light (as it interacts with our sophisticated instruments) is consistent with that interpretation and with no other that has yet been proposed.

Under a given set of conditions (*e.g*. a specific temperature and pressure) all physical actions and interactions are *irreversible*, leading to an *equilibrium* state. For example, under normal summer conditions of temperature and pressure, a block of ice will melt and this process will continue irreversibly until all the ice has become water at that temperature. Thus, in order to understand what can be expected to happen in the physical world, we need to understand the conditions which normally apply and the laws which govern equilibria.

All Sorts and Conditions

The universe as a whole consists almost entirely (*c.* 99.9%) of flaming gases, and these gases consist almost entirely of hydrogen and helium. Out of every 100 atoms, 94 are hydrogen and six helium. In other words, all other atoms make up less than one atom in 100. For example, just one atom in 2000 is oxygen. Hydrogen is the key element for stars being able to release more energy in nuclear reactions than any other element. Below 3000 ^{o}C molecules form, and hydrogen molecules efficiently remove heat away from the stars. Without these functions stars could not form and operate.

The other 0.1% of the universe consists of frozen solids drifting in space (planets, asteroids, comets, meteoroids, dust). The liquid state is so very rare that its relative occurrence is vanishingly small.

What a contrast on Earth! Earth is temperate and wet, and those domains that are accessible to investigation consist almost entirely of oxygen and oxygen compounds.

In dry air, out of every 100 atoms, 78 are nitrogen and 21 oxygen. Nitrogen's relatively unreactive molecules are essential to build air pressure and to dilute oxygen. The proportion of oxygen is quite critical: with less than 15% oxygen, no fire could be lit, whereas at 22% oxygen, forest fires would occur too easily and at 25% even wet vegetation would burn (so lightning would quickly destroy the living world).[22]

The balance between sustaining life and supporting fire is even more remarkable than just indicated. Adult organisms can acclimatise to oxygen levels as low as 12%, though it is likely that effects on reproduction and early development do not allow this to be a permanent condition. However, if atmospheric pressure was increased a little (to 1.66 atmospheres) then the 12% oxygen would have the same partial pressure as in the present atmosphere and life could be normal. But fires would still not be possible, because the heat capacity of this atmosphere will have increased to the point where a flame could not sustain itself at normal temperatures.[23] The design of the atmosphere is very precise.

The Earth's average surface temperature is a warm 15 ^{o}C, so we find vast amounts of liquid water. In water, one out of every three atoms is oxygen and two are hydrogen. Seawater is primarily a dilute solution of common salt (sodium chloride, NaCl) though out of 100 sea salt atoms, ten are still oxygen (38 sodium, 44 chlorine). Sodium, potassium and chlorine play essential roles in the Earth's fluids, both inorganic (oceans, seas) and organic (body fluids, blood, plant sap). Although they are extremely reactive elements, their salts (which contain electrically charged Na^{+}, K^{+}, and Cl^{-} ions) do not react or precipitate with any other common substances. Hence they are vitally important for maintaining fluid concentrations.

It is a useful general rule to remember that reactive elements tend to have unreactive compounds and, conversely, that unreactive elements tend to have reactive compounds.

The rocks of the Earth's outer *crust* consist almost entirely of silicon-oxygen compounds (silica[24] and silicates[25] make up 95% of the crust by mass). Five out of every eight atoms are oxygen and, because the oxygen ion has a relatively large volume, an astounding 94% of the crust's volume is oxygen! The solid earth on which we walk is a well-packed system of oxygen atoms (ions) with small atoms (of mainly eight other elements - silicon, aluminium, hydrogen, sodium, calcium, iron, magnesium and potassium) tucked into the holes between them.

Organisms are systems of carbon compounds (98% of which are compounds of carbon with hydrogen and oxygen) dispersed in a watery medium. On average, one atom out of ten is carbon (six hydrogen, three oxygen). Other elements provide less than 1 atom in ten, e.g. there is on average just one nitrogen atom in every 800. But although carbon is much less abundant than oxygen or hydrogen, it is the key element for life. The attributes of living organisms depend on properties that are unique to large carbon-based (organic) molecules. No other element has the capacity of carbon to form such stable, large and complex structures (e.g. proteins, carbohydrates, fats, and nucleic acids, and the cells, tissues and organs into which they and other organic compounds are built). The balance of carbon and oxygen atoms in the world is critical: a great excess of carbon would use up all the oxygen and prevent the formation of many materials on which life is dependent, e.g. rock and soil. A great oxygen excess would lead to the burning up of all carbon-containing chemicals as noted above.

In fertile, well-aerated soil, the air and water present are essentially similar to those in the atmosphere and hydrosphere. But the solid part of the soil has two components. There is an unreactive sand and silt fraction (mainly silica) which provides the *soil skeleton* that ensures proper soil texture, porosity (aeration, drainage), capillarity, water-holding capacity, fertility, plant root penetrability etc. All fertile soils contain at least 75% sand/silt.

The second component is an active *clay* fraction which contains much more aluminium. The presence of aluminium in silicate rocks promotes one of their main functions: to act as a store of important elements (plant nutrients) which weathering processes release into the soil. When aluminium silicates are weathered, practically none of the aluminium is lost by solution, so the resulting clays contain relatively more aluminium (on average 12 atoms out of 100 compared to three in sand and silt). Clay, in combination with *humus*[26] forms the active soil fraction. This holds plant nutrients strongly enough to avoid too much removal (leaching) by rain, yet loosely enough for them to be absorbed by plant roots.

The air and ocean domains are essentially *homogeneous* (uniform, well mixed - the composition is the same, or nearly so, throughout). The other domains are very *heterogeneous*, e.g. diamonds in one place, gold in another, but only limestone and clay in the garden outside.

Reactions

In the universe at large (interstellar space) there are only gases and these are very thinly spread. Collisions between atoms rarely happen and gravity is unimportant. The opportunities for significant chemistry would appear to be very limited. However nothing could be further from the truth. Most chemistry actually occurs not on Earth, but in the vast space between the stars.[27] For example, there is more alcohol in the average molecular gas cloud than has been distilled in the entire span of human history. But don't head for space - it is so dilute that even in the densest clouds you will have to sift through vast volumes of space to fill a single glass! So how does such chemistry occur in space?

Gases in space are predominantly *plasmas*, i.e. nearly all the atoms present consist of freely moving ions and electrons. Plasmas are found in stars, in interstellar space and around the Earth, including a part of Earth's upper atmosphere (*ionosphere*, *c*. 60-500 kilometres altitude).[28] They are so common - forming more than 90% of the known universe - that they have been described as a fourth state of matter.[29] Most of the plasmas round the Earth come from the Sun. Being electrically charged the movement of the ions and electrons is dominated by magnetic and electrical fields. Space chemistry also occurs on the surface of *cosmic dust* (tiny solid particles, probably of carbon or silicate) or in the shock-heated gas flowing from some stars.

This is a useful point at which to mention *impotence rules*.[30] Throughout human history, scholars and scientists have declared that, by the very nature of things, something or other cannot be done. Historians know of many such rules, and almost all of them have proved to be wrong. Several are relevant here: Aristotle (4th century BC) held that the heavens were made of an element, *ether*, which is unknown on earth and which mortals can never experience; Auguste Comte (19th century) asserted that it is impossible to study the chemistry of the stars; and Sir Arthur Eddington (1926) said that there was no conceivable way that molecules could exist in abundance in space. Impotence rules are sometimes used against Christians, e.g. when it is argued that it is impossible for humans to know the truth, or to draw conclusions about origins, or about the order of the universe. We must not be intimidated by such arguments.

Conditions on Earth are very different from those in space. On Earth, chemistry – even that of gases and plasmas – is dominated by collisions and by the effects of gravity. Indeed under the warm, moist conditions at the Earth's surface, three kinds of interaction will dominate all inorganic chemical activity:[31]

- Reactions involving no transfer of particles, *e.g*. precipitation reactions.
- Reactions involving proton transfer, *e.g*. acid-base reactions.
- Reactions involving electron transfer, *e.g*. some oxidation-reduction (redox) reactions.[32]

A simple example of a reaction with *no particle transfer* is the precipitation reaction between a solution of common salt (sodium chloride) and a solution of silver nitrate. Both are clear colourless solutions, but when they are mixed a white solid (precipitate) immediately appears:

$$Na^+Cl^-_{(aq)} + Ag^+NO3^-_{(aq)} \rightarrow Na^+NO3^-_{(aq)} + Ag^+Cl^-_{(s)}$$

[aq = solution in water; s = solid]

Both solutions contain separate electrically charged atoms (*ions*) as shown. When they are mixed, the silver and chloride ions attract each other strongly enough to form a solid. The other ions remain separate in the solution, but, whether precipitated or in solution, the atoms remain unchanged. Precipitation reactions are common and important, *eg*: in water purification processes.

A simple example of *proton transfer* reaction is the acid-base reaction between a solution of hydrochloric acid and a solution of caustic soda (sodium hydroxide). The hydrogen ions (H^+ = a proton) are transferred from the acid to hydroxide ions to form molecules of water

$H^+Cl^-_{(aq)} + Na^+OH^-_{(aq)} \rightarrow Na^+Cl^-_{(aq)} + H_2O_{(l)}$

[l = liquid]

Acid-base reactions are very common in industrial processes.

A simple example of an *electron transfer* reaction is the redox reaction between a piece of iron and copper (II) sulphate solution:

$Fe_{(s)} + Cu^{2+}SO_4{}^{2-}{}_{(aq)} \rightarrow Cu_{(s)} + Fe^{2+}SO_4{}^{2-}{}_{(aq)}$

The change from Fe to Fe^{2+} (loss of electrons) is an oxidation; the change from Cu^{2+} to Cu (gain of electrons) is a reduction

These are the fundamental kinds of reaction which should be understood in school science. Textbook classifications into 'decomposition', 'combination', 'combustion', 'displacement' *etc*. are useful, but do not really aid chemical understanding. It is like classifying toadstools into 'edible' and 'poisonous' – definitely helpful(!), but it does not further biological understanding of the toadstools themselves.

Natural processes often involve all three types of reaction (*eg* the processes involving calcium carbonate).[33]

The Earth's abundance of water and oxygen compounds (especially CO_2 and carbonates) ensures that acid-base and redox conditions on Earth are rarely extreme. Under normal conditions redox reactions cannot exceed the point where oxygen or hydrogen would be liberated by the decomposition of water. Similarly acid-base reactions are buffered by the interaction between rock carbonate and atmospheric CO_2, so that natural conditions are rarely very acid or very alkaline (basic).

An Impossible World

The most remarkable thing about the domain compositions discussed above is that most of them are physically and chemically quite impossible. They would quite definitely *not* be expected by chemists. The equilibrium compositions expected under Earth conditions for atmosphere and oceans are quite different from what we actually find.[34]

Despite the relative stability of the two-atom molecules, the oxygen and nitrogen gases in the air are actually very reactive. Under Earth's warm moist conditions, the stable form of oxygen is oxide and of nitrogen it is nitrate. It is living organisms which maintain the free gases in the atmosphere. In the absence of life, chemical processes would create a very different Earth. At equilibrium the oceans would be hot saturated salt solutions containing toxic amounts of nitrate, and the Earth would have a high-pressure, carbon dioxide atmosphere.

To teach air or seawater as just a mixture of chemicals, whose properties and industrial uses we discuss individually, is to destroy their meaning and to fail to promote understanding of their chemistry and its significance. It is also far less interesting.

The existence of organisms is particularly unexpected. The principle oxidising agent at the Earth's surface is the free oxygen of the atmosphere. The principle reducing agent is organic material. Since there is abundant oxygen gas in the atmosphere and organisms are, as chemical systems, very highly reactive, they should steadily be destroyed (oxidised) from the face of the Earth.

This is an appropriate point at which to mention other chemical 'impossibilities' facing living organisms. Iron poses an especially crucial problem. All life depends on iron since iron proteins mediate the vital redox reactions at the heart of the chemical reactions (metabolism) of life. But in moist, oxidising conditions, the most stable form of iron is rust. Rust is highly insoluble and forms large aggregates which would kill organisms by choking and blocking the highways and byways through them and their cells. We would all need to drink impossible quantities of water every day simply to stop our kidneys becoming clogged. Fortunately God has created us with special 'anti-corrosion' proteins which bind the iron and prevent rust separating out.

Organisms contain relatively high concentrations of many substances. Water is the most obvious; so obvious that we easily overlook it. Terrestrial animals are very watery systems. Humans are 60-70% water by mass, most vertebrates are about 65%, and some mammals about 85%. Yet most of these animals live in air that seldom contains more than 1% water by mass. Organisms also contain, for example, relatively high concentrations of carbon, sulphur and phosphorus, compared with the minute amounts in their surroundings. If organisms were *closed systems* shut off from their surroundings (like chemicals in reagent bottles on the laboratory shelf) this would be quite unremarkable. Organisms, however, are *open systems* constantly and actively interacting with their surroundings. Yet, while they are alive, organisms show no tendency to dissolve and fade away into their surroundings.

Chemical equilibrium for organisms is attained only after they have died and decayed to dust. However, just like the other domains, the living world as a whole is showing no tendency whatever to come to chemical equilibrium. Clearly we need a better understanding of equilibrium science. That first means a better understanding of the key principles (laws) that govern all chemical and physical processes.

First Principles

All chemical and physical processes are governed by three key principles:

(1) The law of conservation of energy

(2) The law of energy dissipation

(3) The law of least action

(1) The law of conservation of energy

This law states that the total energy of a system[35] is unchanged by any physical interactions. Energy is neither created nor destroyed. One form of energy may seem to disappear, but one or more other forms of energy take its place. The hammer that struck a nail may have stopped moving, but the energy of that movement has not vanished. The same energy reappears as heat (and sound).

Energy and matter (mass) are interconvertible (the famous $E = mc^2$), so, strictly speaking, it is mass and energy considered together that are conserved. However in the chemical and physical interactions of school science, the interconversions of mass and energy are insignificant and can be ignored.

(2) The law of energy dissipation

The law of energy conservation says nothing about the direction in which natural processes go. Yet it has always been noted that some things happen spontaneously with ease, whereas other things never happen at all. For example:

- heat always flows from a hot body to a colder body, but never the reverse;
- a gas always expands to occupy a larger volume, but it never contracts into a smaller volume;
- new clothes gradually wear out, but old clothes never become new;
- a sugar lump dissolves into tea, but never separates out again;
- a living cat grows old and dies, but a dead cat never comes to life;
- the more a tape or disc is copied the more random errors that appear, but a poor copy never generates a good one.

Of course, the use of outside energy and intelligent design can counteract or even reverse some of these processes, but naturally, spontaneously, this never happens. There is a clear *onewayness* in nature, and it is this that is described by the law of energy dissipation. The law states that in any physical interactions, energy is dissipated, *ie* after the interaction, some of it is unavailable for further interactions and transformations in that system. For example, a skier descending a hill can never build up enough momentum to ascend another hill of the same or greater height. In the descent some energy is always dissipated ('lost') as heat and sound (overcoming friction). Even if the skier could collect the heat and sound, the problem would remain: heating the skies or shouting at them will not get him or her back up the hill. More *usable* energy must be supplied from outside the system, *eg* by utilising a ski-lift to get back to the top of the hill.

This principle can be applied to a system in different ways. It describes the unavailability of useful energy in a working system;[36] the disorganisation of a structured system;[37] and the loss of information (production of 'noise') in a programmed system. We have already seen that many familiar phenomena are illustrations of these applications.

The law of energy dissipation is part of God's good creation; it should not be interpreted as a result of the Fall. If it did not hold

- air could spontaneously demix into zones of pure oxygen and pure nitrogen (both fatal);
- the sea could separate out zones of pure water and pure salt;
- warm water could produce areas of hot water and of cold; and
- friction and viscosity ('internal friction' of a liquid = its resistance to flow) would not exist.

We can put this another way by saying that nature (the non-human world) was not created to be a perfect system *in itself.* It was created to be ruled and managed by people who in turn would represent God and mediate his wise and holy rule. Without the caring presence (service) of people, nature deteriorates.[38]

(3) The principle of least action

'Least action' is one of a number of 'variational principles' – least time, least (potential) energy, least action – and is here used as shorthand for them all.[39] Taken together they state that all physical and chemical changes take place in the most economical way, *eg* so that the expenditure of time or energy is minimised. They are sometimes described as the laziness of nature, or that nature acts with the least possible effort. Impressively, it is possible to derive many fundamental principles of science – from Snell's law of optics to Newton's laws of motion and even Schrödinger's equation of quantum mechanics – from such principles. The whole of ray optics follows from the principle that light always follows the path that minimises travel time. Least energy explains a host of mechanical phenomena from the shape of clothes lines, necklaces or overhead power cables to the behaviour of loaded beams. It also lies behind Le Chatelier's principle (see below) and the fact that, in electrolysis, if more than one substance can be liberated at an electrode, then that one which requires the least energy will be preferentially discharged. The principle of least action – least difference between kinetic and potential energy – explains why a ball follows a parabola when it is thrown (or the course of a satellite settling into orbit) and why heavenly bodies orbit in conic sections (circle, ellipse, parabola and hyperbola). Many scholars down the years (e.g. Fermat, Leibnitz, Maupertuis, Planck, Feynman) have commented on the 'mysterious efficacy'[40] of these principles in fundamental physics. To date no one has been able to explain naturalistically why the universe so behaves.

Every aspect of the physical sciences can be related to, and illuminated by, one or other of these three foundational principles.

Equilibrium

Chemical equilibrium is a state of maximum stability under specified conditions. In an earth tremor, chairs and high stools are likely to fall over onto their long sides – their position of maximum stability. Similarly all natural chemical processes tend to proceed towards their state of maximum stability. Chemical stability is determined by the interaction (compromise, balance, adjustment) between two principles which are specific applications of the laws discussed above:

- The principle of minimum (least) energy.

- The principle of maximum disorder (from the law of energy dissipation).

(1) The principle of minimum energy

Substances will tend to interact (react) if by so doing they can proceed to, and remain in, a state of lower potential energy, *ie* the products are less able to interact. The lower the energy the more stable the structure. Only very stable compounds can occur as minerals; less stable ones either do not form, or soon decompose.

Another statement is *Le Chatelier's principle* – that if a constraint (*eg* increased pressure) is applied to a chemical system at equilibrium, a change will take place within the system to counteract (or neutralise) the constraint (*eg* reduce pressure). The *Haber process* for manufacturing ammonia (from nitrogen and hydrogen gases) provides a good illustration.

(2) The principle of maximum disorder

All physical and chemical systems tend to proceed to, and remain in, a condition of maximum disorder (randomness, mixed-upness). This principle sounds destructive, but it is not necessarily so - remember what could happen if air or seawater demixed.

Under some conditions, both principles may determine that a change goes in a particular direction to equilibrium, *eg* a gas expanding into an empty container, or zinc dissolving in hydrochloric acid (in both cases the change is in the direction of both least energy and maximum disorder). For other changes the principles may describe opposite tendencies and the equilibrium then represents a compromise, or balance between them, *eg* oxygen dissolving in water (decrease in energy outweighs increase in order), or ice melting (increase in disorder outweighs increase in energy). At normal room temperatures, the tendency to least energy usually predominates.

Steady as She Goes

The above principles describe the predominant tendency of natural systems to move to a state of equilibrium, or maximum stability. However, some systems can be maintained away from equilibrium *if they continually receive and dissipate large amounts of energy in order to do so*. Such systems are called 'steady state systems' or 'dissipative systems'. In the natural world they are crucial to energy transfer processes and thereby also act as 'safety valves'.

In the atmosphere, the summer Sun causes very great local heating of the air at the ground surface producing enormous differences in temperature from the air high above (in winter large temperature differences are more common over the oceans due to much greater cooling of the air aloft). It is important to the stability of the planetary climate (and thus to human life) that this heat energy is rapidly transferred to cooler areas. If the energy produced by the interaction could build up indefinitely, it would reach fantastic levels and the atmosphere would finally be engulfed by an unimaginable explosion. In fact, efficient energy transfer processes do operate - the excess energy is regularly dissipated by the atmospheric eddies we call storms (thunderstorms, waterspouts, tornadoes, depressions, typhoons, cyclones, hurricanes etc.). Some 45 000 storms arise around the Earth every day: at any moment 2000 are in progress. A summer thunderstorm may dissipate in its lifetime the energy of 12 or so Hiroshima bombs (i.e. about 1 billion kilojoules) and a hurricane may transfer as much energy every second.

The same mechanism operates in the oceans. Large circulation currents can extend over thousands of kilometres and these mix warm surface water with cold water down to depths of hundreds or even thousands of metres. Eddies with diameters of about 100 kilometres (one-tenth the size of atmospheric eddies) spin off the sides of major currents and help to dissipate the current's energy and mix the warm and cold water. These eddies are crucial to energy transfer in the oceans.[41]

These currents and eddies can be plotted by altimeters in orbiting satellites. Major currents cause variations in the height of the sea surface. There is, for instance, a height difference of 1.5 metres across the Gulf Stream. Similarly, eddies can be spotted because they cause depressions in the sea surface. There is no uniform sea-level.

If with heavy rainfall the speed of flow of a mountain river increases beyond what can be sustained in an irregular channel or over a rough surface, then eddies (vortices, whirlpools) arise (*turbulent* flow). The excess energy is rapidly transferred from large to small eddies until it is dissipated as heat. In this way the structure of the river is maintained. Without these 'safety valves' - energy-dissipating eddies (steady state systems) - the river water would eventually 'explode' catastrophically into the air.

We now know one reason why God designed water with a very high specific heat capacity. It is essential to the energy transfers that water mediates, that it can store and transfer large quantities of heat without much change in its own temperature. If it had a low specific heat capacity, its wide and rapid temperature fluctuations would be intolerable to living organisms and the world climate would be much more variable.

All these steady state systems are highly unstable. They are a direct product of the available energy in their surroundings and their development is directly dependent on the energy input. They are generated by a large flow of energy, they persist only so long as the energy input exceeds a critical minimum, and they can expand only if the energy input increases (though all eddies tend to dissipate their energy by breaking up into smaller eddies).

More Elemental Matters

We have already mentioned key roles of some of the chemical elements and much more can easily be added. Here are a few more examples:

Hydrogen, *carbon*, *nitrogen* and *oxygen* all play as fundamental and irreplaceable roles in the chemistry of stars as in the metabolism of living organisms. The different roles interconnect in that, through photosynthesis, sunlight is essential to the metabolism of all green plants.

As well as being the key element for stars, hydrogen also produces energy for living organisms, its reaction with oxygen releasing more energy than any other common element. Thus hydrogenated compounds (e.g. fats) are excellent energy sources. A dog-sized mammal produces about 10 000 times more energy per kilogram of mass than does the Sun.[42]

Hydrogen's physical bond (the 'zip fastener' *hydrogen bond* which can be made or unmade with little change of energy) is vitally important to the functioning of water (the most important of all chemical compounds) and of key organic compounds such as proteins and nucleic acids.

As well as being the key element for inhabitable planets (water and silicon compounds), *oxygen* readily accepts electrons and lies at the centre of the redox processes on which life depends.

Silicon is the key element of the rocky crust and of the soil skeleton. Its absence from school science, except in connection with modern technology (computer chips), is a serious (and revealing!) omission. *Aluminium* is in our syllabi, but its vital role in soil is generally ignored.

Calcium and *magnesium* are key elements for skeleton formation. What is important is that they provide some easily soluble compounds (e.g. hydrogen carbonates, chlorides, nitrates) - so the elements are readily available and can be transported in rivers and body fluids - and some hard insoluble solids (e.g. carbonates, phosphates) so that hard parts such as shells, bones and teeth can be built up. Their two-valent ions are also important for linking and cementing other substances, both inorganic (sediments) and organic (cell walls, blood clotting, precipitation of milk protein in the stomach etc.).

Sulphur and *phosphorus* are key elements in energy transfer processes. In organisms they are especially prominent in compounds acting as links between the fundamental redox reactions and cellular activities (e.g. ATP). The divalent sulphur has long bonds and so readily cross-links other substances (e.g. sulphur bridges in the keratin proteins of hair, horn, and nails).

Integrated Science?

We now have the overall framework into which all the usual content of physics and chemistry curricula can be integrated. At all times we must seek to establish the creational roles of things as the critical background for the evaluation of human use and misuse.

Appendix: First Principles of Evolution?

The 'first principles' examined above describe a world that is running down, a world of things that are dispersing, wearing out, ageing and dying. Nevertheless we have seen that there are systems that do increase their organisation and information content. Thunderstorms, for example, generate in their short life a very complex 'cellular' structure. Despite their complexity, these steady state systems can be explained in terms of the physical and chemical properties of the substances involved and their interactions under Earth conditions. But there are also other kinds of exception, *eg* machines and buildings being constructed, or organisms growing from seeds and eggs. The latter are commonly regarded as basically steady state systems. It is therefore widely assumed that theories of evolution meet no obstacles from the physical sciences.

However, the latter systems develop only if two conditions are fulfilled:

(1) the system is an *open* system, *ie* energy can enter and leave.

(2) *usable* energy (energy of the *right kind*) is available, *eg* short wavelength radiation from the Sun.

Evolutionists commonly assume that, because the Earth is an open system and plenty of energy is available from the Sun, there is therefore no problem about evolution.[43] But there certainly is. It is true that for the whole system (*ie* including the Sun) the overall result is an enormous increase in disorder (as the Sun runs down), even if order increase (evolution) occurs locally on Earth. The evolutionary increase of order on Earth will also be temporary as the Sun will eventually die. But this still does not account for evolution. All real systems are actually open systems, but most normally proceed in the direction of increasing disorder. Usually, the more energy that comes into an open system, the more will be the increase in disorder. Let a bull into a china shop, or look at the result of a major explosion, or earthquake! The law of energy dissipation itself is not the problem here. Rather the problem is that we have *very strong empirical grounds* for concluding that increasing order never occurs – even in open systems – unless two further conditions can be met:

(3) a *programme* to direct the development of order, *eg* a designer's plans and specifications, or the developmental information encoded in the DNA and cell structure of seeds and eggs.

(4) a *mechanism* to *store* the incoming energy and *transform* it into the specific form needed for the development, *eg* tools and equipment in artificial construction; metabolism (including photosynthesis) in organisms.

Even with open systems and plenty of energy, no instance of order increase is known without conditions **(3)** and **(4)** also being fulfilled (Table 1.4). To date no theory of evolution has been able to suggest plausible natural sources of either a directing 'programme', or an energy converter (Table 1.5).[44]

Table 1.4 Conditions for Order Increase in Open Systems[45]

Criteria to be Satisfied	System	
	Growing Plant	**Building Construction**
Open system	Seed	Construction site with building materials
Usable energy	Solar energy	Electricity, fuel, human labour
Directing programme	Developmental (cellular) system, genetic code	Architect's plans
Conversion mechanism	Photosynthesis	Workmen and their equipment

Table 1.5 Conditions for Order Increase in Evolving Systems[46]

Criteria to be Satisfied	System	
	First Living Organism	**Complex Organisms**
Open system	Complex inorganic and organic molecules	Simple organisms
Usable energy	Solar energy	Solar energy
Directing programme	None	None
Conversion mechanism	None	None

To say that the Sun powers evolution on Earth is a totally inadequate response. Niagara Falls releases enough energy to fly a jumbo jet, but that energy cannot be so used without some very sophisticated technology to harness it. The availability and quantity of energy are not themselves the solution of the problem of flight. At the present time, the appeal of evolutionists to open systems, solar energy, and vast ages to secure their theory, can only be judged a prevarication.

4 Biological Sciences

What is Life?

> Life is never a material, a substance to be moulded. If you want to know, life is the principle of self-renewal, it is constantly renewing and remaking and changing and transfiguring itself.[47]

Organisms are *generative systems*, i.e. the fundamental characteristic of living things is generative activity in a cycle (life-cycle) of development. Considered chemically, living things are constantly interchanging atoms, groups of atoms and particles; they are made up of compounds on the edge of instability.[48]

All the atoms of our body, even of our bones, are exchanged at least once every seven years. All the atoms in our face are renewed every six months, all our red blood cells every four months and 98% of the protein in the brain in less than a month. Our white blood cells are replaced every ten days and most of the pancreas cells and one-thirteenth of all our tissue proteins are renewed every 24 hours.[49]

Hence life can exist only in a liquid medium. In a solid the atoms are fixed too rigidly into the crystal structure for such vital interchanges to be possible; in a gas, by contrast, the atoms have too little contact.

This generative activity allows organisms to replace parts as they wear out and become damaged, and to continually adjust structure and function to their needs. The wonder of life is that, in the midst of this whirlpool of chemical activity, we all remain the same people.

Organisms are not, however, merely a special kind of physical steady state system. They are *homeostatic systems*. Like steady state systems they maintain a characteristic and developing form, but unlike steady state systems they are able to do so in changing environments against wide variations in energy input (as, e.g., in hibernation and, extremely, in anhydrobiosis[50]). In the absence of an adequate energy flow, steady state systems collapse, but various organisms can survive for long periods when dried or frozen. Even more remarkably, brine shrimps can survive for years in oxygen-free water with no detectable metabolism (energy processing) occurring.[51]

If this assessment is correct, then all biological statements will have a fundamental reference to generative activity. This immediately suggests different avenues and directions for research. One particular approach will be described below, not because we know it to be true (there is presently no decisive research available), but to illustrate that alternatives to Darwinian evolutionary orthodoxy are possible, and are being pursued within the biological sciences. Furthermore this approach actually continues a pre-Darwinian (creationist) tradition, so even if ultimately shown to be wrong, it does at least demonstrate that creationist approaches are compatible with scientific research and with theory production and testing.

The Form of Life

In this approach[52] it is maintained that biological form is established by the organism itself, not imposed by the environment.[53] It spurs a search for laws of biological development which will determine which organisms, out of the myriad of plants and animals which could exist, are developmentally possible, i.e. can actually develop as viable organisms. It is assumed that the possibilities are very limited, even that they are not much greater than the presently known variety of animals and plants.[54]

That this might seem a very strange suggestion simply illustrates how much our thinking has been influenced by Darwinism. It is actually the normal mode of thinking in other areas of science. For example, planets, meteorites, and comets, cannot be found in every conceivable type of orbit; only conic section orbits - circles, ellipses, parabolas and hyperbolas - occur. These limited possibilities are set by the inverse square law of gravitation.

Changes in biological form will be determined and limited by the pre-existing structure. Interactions which affect development (e.g. gene mutations and environmental modifications) can only *trigger* those changes which are permitted by the lawful structure of the developing organism. The existing evidence does indeed indicate that gene mutations are actually of very limited types and that their actions do not create, determine or even select the forms. The hierarchy of classes in biological classifications (e.g. phyla, classes, orders, families, genera, species) would then be seen to reflect a hierarchy of kinds of developmental process. Current Darwinian theories of evolution (based on chance and natural selection) would be unmasked as not scientific theories at all, i.e. as not based on well-tested theories of development. On the contrary they would be assuming ideas about development which would then be known to be wrong.

This is an appropriate point at which to mention a significant logical problem with the claim that there are in existence scientific theories of evolution. One of the biggest gaps in modern biological theory is that there is no theory of (embryological) development. The problem, of course, is that if there are no scientific theories of development, *then neither can there be scientific theories of evolution*.

As noted above, this *structuralist* approach is an evolutionist development of a pre-Darwinian (or *Newtonian*[55]) creationist tradition. In that tradition it was assumed that the natural kinds of animal and plant were both irreducible (i.e. not evolved) *and* optimally designed. Nevertheless these creationists still assumed that much scientific investigation and theory construction (in embryological terms) was still called for as outlined above. Creationism is not a 'science-stopper' and that common calumny should be dismissed.[56]

Under the dominant Darwinian point of view genes are seen as primary instructions responsible (as blueprint or recipe) for every feature of organisms. All changes (gene mutations) are held to be possible, or even equally likely. Hence the number of forms (actual animals and plants) is held to be theoretically limitless.[57]

Hence, it is easily assumed that there have been innumerable 'wonderfully fine gradations'[58] in the lines of descent and that most organisms (at least 99% - all the 'missing links') must be extinct. However, the evidence points to an opposite conclusion - known living species outnumber those known only as fossils by at least ten to one.[59]

Consequently, scientists hardly look at animal and plant forms at all and morphology, as a scientific discipline, is almost extinct. The majority of today's biologists are really chemists (biochemists and molecular biologists of various specialised kinds). Since the world of biology reflects the dominant ideologies it is vitally important that we develop a thorough critique.

A Life-Controlled World

By their high activity organisms speed up the slow natural cycles, and, in so doing, maintain themselves and the rest of the world in a steady state far removed from chemical equilibrium.

Through the key processes of respiration and photosynthesis (the world's most important redox reactions!), organisms entirely renew the carbon dioxide in the air every few years, and even the much larger volume of oxygen is renewed in about 2000 years. Most incredibly of all, even the 11 billion, billion metric tonnes of water on the Earth are eventually split and reconstituted by the activities of living things.[60] It would seem incredible, because the biosphere is such a very thin film on the Earth's surface (it is spread throughout the oceans of course, but incredibly thinly).[61] Compared with the depth and volume of the atmosphere, hydrosphere or crust, the biosphere is insignificant. For every atom in the biosphere, there are about 700 in the atmosphere, 400 000 in the hydrosphere and 2 000 000 in the crust! Yet this insignificant 'scum' maintains most of the rest of the world in a steady state adjusted optimally to its own needs. So accurate is the biosphere's system of balances and adjustments that, for example, the oxygen concentration in the air has not measurably varied during the 80 years for which accurate measurements have been available.[62]

However, in recent centuries one particular domain of the biosphere has been rapidly expanding and has, in the 20th century, become abnormally reactive - the domain, of course, of people.

People: Converters or Corrupters?

If plants are 'producers' (food makers) and animals are 'consumers' (food takers), then people are predominantly 'converters' (changers, transformers), converting vast amounts of the Earth's raw materials into forms suited to their own activities. In so doing, humankind is accelerating certain parts of the slow chemical transits of the physical world and interacting vigorously with the fast cycles of the biosphere. However, there is a major problem. The processes of the physical and living worlds have been designed by the Creator for the permanent sustenance of an optimal environment for living things. Our present activities, on the other hand, are neither self-supporting nor self-renewing. We are rapidly using up the accumulated 'capital' resources of God's world, without any means of renewing them. In so doing we are poisoning the environment, harming both our societies and ourselves in the process. We are creating pollution problems of such monstrous proportions that they threaten to swamp the otherwise more than adequate tolerance margins that are part of the world's design.[63] In contrast to the noiseless, low-energy, economical, self-balancing and self-cleansing activities of the other living domains, our noisy, high-energy, 'brutal' and wasteful activities clearly conflict violently with God's ways for His world.

All of Life is Religion

The interrelating and interacting domains of the world clearly fall into three categories. The three foundational domains (atmosphere, hydrosphere, crust) are *physical* domains, i.e. they are primarily domains of physical activity which should be governed by the normal physical *irreversible* trend to *equilibrium* and be characterised by slow, low-energy movement of the elements.

The two basic domains of the living world (of plant producers and animal consumers) are *biological* or *psychological* domains, i.e. they maintain *homeostatic* (non-equilibrium) states by the continual expenditure of energy and are characterised by fast, high-energy *cycles* of the key elements. By so enormously speeding up the slow natural movements, they radically alter the composition of the foundational domains, maintaining them in steady states far removed from equilibrium.

People have a *religious life* which links them to spiritual reality. In the other domains, created things obey the Creator's laws necessarily or instinctively, but people are responsible to their Creator. They can choose to learn the Creator's ways and submit to His laws, or else choose to be ignorant of them, or deliberately disobey them. If they are not in relationship with their Creator, then they are under other, demonic, spiritual influences. *There is no spiritual neutrality*. The world of Western secularism is no less spiritual than the world of Marxism, of Islam, or of the New Age.

In the last century, Western industrial activities have accelerated parts of the natural cycles, but in such 'violent' disregard of the Creator's ways, that the present human world system is not sustainable. The non-renewable, capital resources of God's world are being used up rapidly and wastefully and a vast world-threatening pollution is being produced.

Notes

[1] Put in technical terms, it appears to contradict the Law of Conservation of Angular Momentum.

[2] Big bang theory assumes an unbounded universe, i.e. a universe with no centre and no edge. Rotation around an axis implies a centre of mass and thus a boundary on the mass of the universe. Put another way, the Cosmological (or Copernican) Principle would be violated. This is the Principle that an observer's view of the universe is essentially the same regardless of his location or the direction in which he looks. It is an unproven assumption, but basic to modern cosmology. Indeed it is really a metaphysical belief adopted to avoid the postulate of a centre and the possibility (consistent with present observations) that Earth is at or near that centre. See John Byl, The role of belief in modern cosmology, in Jitse van der Meer (ed), *Facets of Faith and Science*, Vol. 3: *The Role of Beliefs in the Natural Sciences*, Lanham, MD: University Press of America, 1996, Chapter 4, pp 47-62. On rotation see D. Russell Humphreys, *Starlight and Time: Solving the Puzzle of Distant Starlight in a Young Universe*, Colorado Springs, Colorado: Master Books, 1994, pp 18-19, 86-89, 127-128, and Cosmic axis threatens big bang, *Creation Matters*, **2** (3), 1997, pp 4,6.

[3] For example, the stars have to be as distant as they are because otherwise gravitational interactions would destabilise planetary orbits, and radiation levels in the solar system would regularly become too high for life to survive.

[4] The Anthropic Principle comes in several versions (weak, strong, participatory etc.), but is essentially a recognition that conscious beings can only exist in a universe with very special characteristics.

[5] For a review by a Christian astronomer see Hugh Ross, Astronomical evidences for a personal, transcendent God. In J.P. Moreland (ed), *The Creation Hypothesis: Scientific Evidence for an Intelligent Designer*, Downers Grove, ILL: InterVarsity Press, 1994, pp 141-172. For a secular review see John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle*, Oxford: OUP, 1988, 706 pp.

[6] In our galaxy only 4% of stars are yellow stars burning hydrogen into helium at their centres (known technically as G-type main-sequence stars).

[7] More than half of all stars appear to have one or more companions (binary or multiple star systems).

[8] Nearly all stars in the Milky Way are less massive than the sun and 95% are intrinsically less luminous (70% are red dwarfs).

[9] Carl Murray, Is the solar system stable?, *New Scientist*, **124** (1692), 25 November 1989, pp 60-63.

[10] Stuart Henderson, Minor readjustment (letter), *New Scientist* **142** (1919), 2 April 1994, p 43; Ian Stewart, One hundred and one dimensions, *New Scientist*, **148** (1999), 14 October 1995, pp 28-31 (p 29); John Barrow, *The Artful Universe*, Oxford: OUP, 1995, pp 145-149.

[11] Lou Bergeron, How the seabed saves the world. *New Scientist*, **149** (2015), 3 February 1996, p 15

[12] Adapted in line with Part II, section 3 of this chapter from information in Robert Costanza *et al*., The value of the world's ecosystem services and natural capital, *Nature* **387** (6630), 15 May 1997, pp 253-260, and James Lovelock, *Gaia: the Practical Science of Planetary Medicine*, London: Gaia Books, 1991, 192 pp.

[13] Debora MacKenzie, Danube's deadly lesson for sea life, *New Scientist*, **153** (2075), 29 March 1997, p 4.

[14] Tremors are triggered either by the weight of water or by leaks lubricating fault lines. The worst acknowledged case was in India in 1967 when the Koyna reservoir near Bombay triggered a magnitude 6.5 earthquake in a previously nonseismic region. The dam broke, drowning 177 people (Fred Pearce, Dam villagers await the apocalypse, *New Scientist*, **153** (2071), 1 March 1997, p 8).The growing disquiet about dams is reflected in the statistics: in the 1960s 1675 dams were built in the USA; in the 1990s as of the end of 1996, only 63 (*1997 Britannica Book of the Year*. Chicago: Encyclopaedia Britannica, 1997, p 142).

[15] Fred Pearce, Living sea walls keep floods at bay. *New Scientist*, **150** (2032), 1 June 1996, p 7.

[16] Elisabeth Geake, A little flood goes a long way..., *New Scientist*, **141** (1907), 8 January, 1994, p 17. The dangers of dykes were dramatically illustrated in August 1997 by the flooding of Ottery St Mary (Devon) where the flood plains of the river Otter had been used for building.

[17] For a pertinent example see *Calcium* (chapter 4 in this book), and for further challenging reading, Robert Chambers, *Whose Reality Counts? Putting the First Last*, London: Intermediate Technology Publications, 1997, 297 pp., Michael Jacobs, *The Politics of the Real World: Meeting the New Century*, London: Earthscan, 1996, 146 pp., Jeremy Seabrook, *Victims of Development: Resistance and Alternatives*, London: Verso, 1993, 250 pp.

[18] The average loss is somewhere between 20% and 40% - see, e.g., Fred Pearce, Just too much water to swallow. *New Scientist*, **140** (1901), 27 November 1993, pp 44-45.

[19] See Ernst von Weizsäcker, Amory Lovins and Hunter Lovins, *Factor Four: Doubling Wealth - Halving Resource Use*, London: Earthscan, 1997, 322 pp (pp xx-xxi). Another of their many examples is that, in the production of a largely home-produced German yoghurt, some 8000 kilometres are travelled in collecting the milk, strawberries, packaging and other materials (pp 117-119).

[20] Many pet breeds may look fancy, but are biologically deformed. Our pet breeding practices deserve as much censure as those of intensive farming or vivisection.

[21] Jules Pretty, Could sustainable agriculture feed the world? *Biologist*, **43** (3), 1996, pp 130-133.

[22] James Lovelock, *Gaia: The Practical Science of Planetary Medicine*. London: Gaia Books, 1991, 192 pp (pp 114-116).

[23] D. Drysdale, Burning issue (letter), *New Scientist* **145** (1967), 4 March 1995, p 58.

[24] Silicon dioxide, SiO_2, e.g. quartz.

[25] Complex compounds based on SiO_4 units.

[26] Organic material resulting from the decay of dead plants and animals.

[27] Marcus Chown, The lab between the stars, *New Scientist*, **148** (2008), 16 December 1995, pp 44-45.

[28] Present-day spaceplanes (e.g. the NASA space shuttle) get so hot on re-entry that the surrounding gas ionises forming a plasma. Since radio waves cannot pass through these plasmas, there is a communications blackout for several minutes (Ian Iannotta, Breaking the heat barrier, *New Scientist*, **155** (2097), 30 august 1997, pp 28-31 (see p 28).

[29] Yaffa Eliezer and Shalom Eliezer, *The Fourth State of Matter: An Introduction to the Physics of Plasma*, IOP Publishing, 1989, 240 pp.

[30] See Robert E.D. Clark, *God Beyond Nature*, Exeter: Paternoster Press, 1982, 112 pp (pp 48-49).

[31] In the real world, these are dominant peaks in a continuum, e.g. when hydrogen chloride is formed from its elements, the electron transfer from hydrogen to chlorine is only partial.

[32] Sometimes redox reactions are interpreted in terms of electron transfer, but this is a mistake. The concept of *oxidation-reduction* is arbitrary (though very useful) and includes reactions in which there is no particle transfer (*e.g*. the combustion of carbon). The redox concept is best defined in terms of change in *oxidation numbers*. See Marten ten Hoor, Oxidation and reduction now, *School Science Review*, **78** (284), 1997, pp 112-116.

[33] See *Calcium* (chapter 4 in this book).

[34] For more details, see chapter 4, *Atmosphere and Ocean*.

[35] system = any complex whole from molecules, to machines, to galaxies.

[36] For example, it is impossible to convert all the energy released by the combustion of petrol in a car engine into energy of movement of the car. Some of the energy is always lost as heat, sound, and in engine wear.

[37] Everything artificial has to be maintained, or it steadily degrades, wears out, or ceases to function effectively.

[38] Needless to say, it deteriorates even faster in our *un*caring presence.

[39] See Wolfgang Yourgrau and Stanley Mandelstam, *Variational Principles in Dynamics and Quantum Theory*, London: Pitman, 1968, 3rd edn, 201 pp; Don Lemons, *Perfect Form*, Princeton NJ: Princeton University Press, 1997.

[40] Robert Matthews, The brothers Bernoulli, *New Scientist*, **156** (2103), 11 October 1997, p 51.

[41] See Daniel Clery, Europe's orbiting ocean plotter. *New Scientist*, **130** (1766), 27 April 1991, pp 41-45.

[42] Reported by Roger Revelle (History of the universe: introduction, *Proceedings of the National Academy of Science of the USA*, **52** (2), 1964, p 523). He gave no details, but I carried out the calculations in 1983 (unpublished) and confirmed a value of *c*.10 000 for an average-sized dog (my results varied from *c*. 2000 for an elephant to *c.* 212 000 for a shrew).

[43] A helpful discussion is provided by Del Ratzsch, *The Battle of Beginnings: Why Neither Side is Winning the Creation-Evolution Debate*, Downers Grove, Illinois: IVP, 1996, pp 91-96. See also the literature cited in Section 8 Thermodynamics, in Chapter 5 of this book.

[44] Thus Charles Thaxton *et al* distinguish *configurational* (*selecting* and *coding*) entropy from *thermal* entropy and conclude that, '... negative thermodynamic entropy has nothing to do with information, and no amount of energy flow through the system and negative thermal entropy generation can produce even a small amount of information. You can't get gold out of copper, apples out of oranges, or information out of negative thermal entropy.' (C.B. Thaxton, W.L. Bradley and R.L. Olsen, *The Mystery of Life's Origin: Reassessing Current Theories*. New York: Philosophical Library, 1984, p 183).

[45] Tables 1.4 and 1.5 are adapted from Henry Morris and Gary Parker, *What is Creation Science?*, El Cajon, California: Master Books, 1987, 2nd edn, pp 212-213.

[46] Evolutionists regard natural selection as a ('blind') directing programme and the process of mutation as providing a conversion mechanism, but these suggestions lack empirical support.

and can only be regarded as highly implausible. See Chapter 2 for further discussion of evolution.

[47] Boris Pasternak, *Doctor Zhivago*. London: Flamingo, 1984, p 373 (First published in English in 1958).

[48] In the terms of chaos and complexity theories, living organisms are 'complex adaptive systems' that function on 'the edge of chaos'.

[49] Edmund Ambrose, *The Nature and Origin of the Biological World*. Chichester: Ellis Horwood (John Wiley), 1982, pp 19, 87, 176.

[50] Anhydrobiosis refers to organisms which survive adverse conditions by producing forms which tolerate extreme desiccation, e.g. many rotifers.

[51] What is remarkable is that these brine shrimps are still fully hydrated and at room temperature. Under these conditions, gradual deterioration from random damage would be expected. See Bob Holmes, Shrimps challenge meaning of life. *New Scientist*, **153** (2068), 8 February 1997, p 15.

[52] This approach is called *developmentalism, structuralism* or *process structuralism*. For a recent critique, see Paul Griffiths, Darwinism, process structuralism, and natural kinds. *Philosophy of Science* **63** (3), 1996, pp S1-S9.

[53] Although obviously organisms can exist only in environments that support their form.

[54] This is the view of some developmental biologists, eg, Brian Goodwin, *How the Leopard Changed its Spots: The Evolution of Complexity*. London: Weidenfeld & Nicolson, 1994, 233 pp.

[55] So-called because of the analogy with Newtonian mechanics.

[56] See Part II, Section 5 of *Evolution or Creation?* (Chapter 2 of this book).

[57] Biologists do, of course, take account of physical constraints (e.g. gravity and the nature of naturally available materials). Some also argue that previous evolution (e.g. a particular pattern of development) constrains later evolution, but this can hardly apply in the long-term (see PartIV, Section 5 of Chapter 2).

[58] Charles Darwin, *The Origin of Species*, London: J M Dent & Sons (Everyman), 1956, 6th edn, p 228 (the 6th edition was first published in 1872).

[59] See Part V of *Evolution or Creation?,* (Chapter 2 of this book).

[60] Plants constitute 99% of the world's biomass. Even fungi are estimated to have twice the total biomass of animals.

[61] It has been discovered recently that some microbes do live deep beneath the Earth's land surface, namely SLIMEs (Subsurface Lithoautotrophic Microbial Ecosystems) which rely on hydrogen generated by chemical reaction between water and iron (II) silicates in basalt rock. They have been found more than 1000 metres below the Earth's surface. It appears that they are not dependent, even indirectly, on sunlight, nor on geothermal warmth, nor on buried organic matter (Larry O'Hanlon, Low life would be at home on Mars. *New Scientist*, **148** (2001), 28 October 1995, p 19).

[62] Knut Schmidt-Nielsen, *Animal Physiology: Adaptation and Environment*. Cambridge: CUP, 1997, 5th edn, p 6.

[63] See, e.g., Vaclav Smil, *Cycles of Life: Civilization and the Biosphere*, Scientific American library, 1997, 256 pp.