Rational Universe, Irrational Odds

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Acknowledgements

I wish to thank the following people who have contributed so much and in so many different ways to the research, preparation and writing of this book:

MUSTAPHA NIWAZ

For all his guidance in the seeking of knowledge and his help in developing a more readable book. Also for introducing me to the science of life.

SHAKIL SHAYISTA

For his assistance in the research and development of this book, and for his nagging me to finish this book.

IMAM HUSSEIN BETHUNE MOSQUE,

For his endless support where perhaps I would have faltered.

DAVID ROLLIN.

For the many hours of discussion on the Bible and religion.

JAMAL HARWOOD.

For proof reading and correcting the draft manuscripts as well as all the helpful comments and suggestions

TAQIUDINE AN NABAHANI.

For the inspiration and clarity which his numerous books have given me and which have shed light on the subject at hand.

My thanks also to all other people who have helped me in my research and study for this book, the list of names of whom would be longer than the book itself.

Dedication

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Preface

"I must thank you," said Sherlock Holmes, "for calling my attention to a case which certainly presents some features of interest." **The Hound of the Baskervilles**

I hope you consider this book, not just as any other book, but more of a personal dialogue between you and myself. As you read my book, I would like you to decide for yourself, if what I have written is true or false. I would like you to behold a court case! - I will present my case and evidence and you are to assume the role of prosecutor, judge & jury. I advise you to use your mind and gather your evidence, to make efforts to disprove my case. Please also make a verdict at the end of this 'hearing' to decide if what I write is true.

This book will give you an insight into how you can discover and prove the existence of a Creator, using the most powerful tool - The human mind and it's ability to reason. It is your ability to reason that allows you to ask questions about your existence, the origin of the universe, what happens after death and about the existence of God. It is because of your ability to reason that gives rise to your human conscience, which separates you from the rest of life on earth. Using your ability to reason, you should be able to discern for yourselves what is correct or otherwise.

You should begin with an **objective** and **open** mind, and seek to **understand** and gain **knowledge** and **truth**. Do not allow any **biases**, **prejudices** or **pre-conceived beliefs** cloud your reason and common sense. I urge you also to strongly to examine all references given in this book, as most of these are readily available in many public libraries.

This book has been written with the intention of making it understandable to the widest possible audience. Therefore, the scientific jargon was deliberately kept out as much as possible. However, sometimes it was impossible, to exclude any scientific terminology. Do not worry! There are footnotes for those of you who may get completely lost.

It is said that every mathematical formula or expression included in any book would reduce the readership audience by half. Since I have a personal dislike for complicated mathematics, I have delegated most of the mathematics to a few chapters where the subject is essentially mathematical in origin.

I would appreciate any material which the readers may have, which might make the book more understandable or a particular point clearer. I eagerly await your response. Finally I am sure you will not blame me for any mistakes or poor explanations of scientific terms and phenomena.

Introduction

A little reasoning

"How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?" **The Sign of Four**

While looking into the night sky, I am completely awe-struck by the immense size of our universe and by the countless number of stars like heavenly ornaments that adorn the sky. Intrigued by that vast blackness with its seemingly unfathomable secrets, I think to myself, will we ever truly unravel all the secrets of the universe some day. People have from time immemorial asked the great questions: What is its origin? Does it have a purpose? Why are we here and is there a Divine Creator and Designer who fashioned the universe? These are questions we all ask ourselves at one time or another in our lives, however the answers to these questions affect how most of us behave and how we look at life. Some people are satisfied with the answers they get, some do not care one way or the other.

The answers we often get or conclude are not always satisfactory and in most cases vary for different people. This is because we normally look only to our society and the existing ideas and systems around us for the answers and solutions. We all mould our lives according to the concepts we have about life and the universe.

Animals seem to be aware of the physical world around them to a greater or lesser extent, and are able to respond to it, but unlike the rest of life on earth, as humans we have the ability to reason, search and question our existence and origin. We posses the ability to understand, to predict events and manipulate natural processes to our own ends.

In this respect we seem to be infinitely removed from the other forms of life on earth. It is this ability of reasoning, searching and questioning our existence and origin, which gives rise to our human conscience, and separates us from the rest of life on earth.

Today, in an age of science, our understanding has vastly expanded. Since it is very difficult for us to fully comprehend the metaphysical[1], and philosophical concepts about our existence such as why we exist? Is there a Creator? Do we have an eternal soul? And is there life after death?

We must first look to the physical things around us for answers. We must use 'reasonable arguments' That is to say we must examine 'man', 'life' and the 'universe'. If we examine 'man', 'life' and the 'universe' briefly we can logically reason out and better understand the metaphysical.

However, is our human reason suspect or subjective and influenced by preconditioning? Are we being excessively chauvinistic in supposing that we can successfully apply the human mind to the great issues of existence?

Our minds are extremely successful in framing an understanding of those parts of the world our five senses can directly reach. It may be no surprise that the human mind can deduce through reason the laws concerning falling objects, because our mind can devise strategies for dodging them. But do we have any right to expect extensions of such reasoning to work when it comes to nuclear physics, astrophysics or quantum mechanics? The fact that it does work, and works 'unreasonably' well, is a testimony that the 'human reason' **is** reliable.

Vindicating reason somewhat gives rise to another question. If human reasoning is able to deduce something of the structure of the physical universe, would it be true to say that the universe is just a manifestation of reason? We use the word 'rational' to mean 'conformity with reason', so the question is whether, or to what extent the universe is rational. Science and the scientific method are founded on the hope that the universe is rational in all its observable aspects.

[1] Theoretical philosophy of being and knowledge of things beyond reasoning.

It is possible that there are some facets of reality which lie beyond the power of human reasoning. However, this does not mean these aspects of reality are necessarily irrational in the absolute sense. We have to be aware of the possibility that there maybe some things with explanations that we could never understand and maybe some others with no explanation at all. All people hold 'religious beliefs'[2], most of which appear irrational to the scientific method.

That they may appear irrational or unscientific does not mean they are wrong. Perhaps there is a route to knowledge such as '**Revelation**' or '**Divine Inspiration**' that bypasses or transcends 'human reason'?

Because we want to uncover the answers to those questions about our origin and the existence of a creator *(I will term these questions as the 'Fundamental Questions')*, we should leave any religious pre-conditioning behind. Before using reason, we should understand that there are two types of reasoning which the human mind commonly uses, as it is important to make a distinction between them.

The first is called 'deduction'. This is based on the rules of logic. According to logic certain statements such as 'a cat is a cat' and 'everything either is, or is not a cat,' which are accepted as true, while others like ' a cat is not a cat', are deemed false. Deductive logic is based on set of statements called 'premises', which are held to be the case without further questioning.

When deductive logic is applied to complex sets of concepts , the conclusions can often be surprising or unexpected, even if they are the working out of the original premises. An example is Einstein's use of, Maxwells and Lorentz's[3] Equations to deduce his famous equation: $\mathbf{E = mc^2}$.

The second form of reasoning that we employ is called 'inductive'. Like deduction, induction starts out from a set of given facts or statements, and arrives at conclusions from them, but it does so by a process of generalisation rather than sequential argument. An example of inductive reasoning is the prediction that the sun will rise tomorrow, based on the fact that the sun has faithfully risen every day so far in our experience.

The scientific method is based on hypotheses which are tested for by experimentation and predictions based on reasoning of this kind, resulting in theories and laws of physics e.g. the Newtonian Inverse Square Law is called a Law, because, on the basis of induction, we reason that the inverse square property will always hold true.

It is generally agreed that logico-deductive arguments constitute the most secure form of reasoning of the two. The only place where it is called into question is in quantum physics. We will look at quantum effects and their connection with the 'Fundamental' questions' in the chapters ahead. From this understanding of 'human reason', before we continue we should limit our search with the following conditions:

1. We limit our search with the **reality**[4] around us that we can **observe** or **sense** with our five senses.
2. We do not make arbitrary **assumptions** or **guesses** i.e. premises which are not mutually consistent **and based on reality**[5]**.**
3. The answers or truths we find should be proven true whatever our background, religion or experience i.e. We should come to the same **objective conclusions** based on the same objective realities, whether we are a Scientist, Atheist, Christian, Jew, Hindu, Muslim, Aborigine or Eskimo.

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[2] Man posses three distinctive instincts: The 'Survival Instinct' and the 'Procreational Instinct' Man shares with other animals. The third is the: 'Spiritual or Reverence Instinct' which is unique to man. This instinct is gratified in man by his reverence or worshipping of something - be it in the religious sense of worshipping; a mountain, river, the sun, the unseen spirit world, an idol or an all powerful Creator - or a material, abstract or undefined sense like worshipping; money, a personality e.g. Marx and Lenin, fame and glory of others e.g. Pop Stars or even concepts like freedom. Therefore even the athiest holds some sort of belief system which provide the way to satisfy this inscinct.

[3] In the context of the Michelson and Morley's experiments on the measurements of the speed of light.

[4] By this I mean that which is real for all of us and independant of us, i.e not our dreams or imaginations

[5] By this I wish to also eliminate any 'what if's', 'maybe's' and those theories and hypothese which are based on nothing more than pure conjecture, or mathematical trickery.

If we begin our search by looking at Man[6], we see that Man is finite in all his attributes, that is to say, we have a limited span of life, height, weight, and amount of knowledge. We are born, we grow to adulthood then we die. A person for example could be six feet tall but never sixty feet tall, or sixty years old but never six thousand. You could conclude by saying Man is limited.

When we next look at 'life' in general, we can see that it manifests itself in plants and animals which in turn grow old and die, after a finite period, at which point one can state that, 'that particular life has come to an end'. A tree for example might live for up to 3000 years but never 3000000 years. It can be concluded that life therefore is also limited.

If one finally examines the universe one finds that, this vast universe is composed of magnificent celestial bodies like the galaxies, stars, planets and moons. These celestial bodies all have a certain finite size and mass.

They also have a beginning, exist for a finite period and eventually end, although on a much longer time scale than that of ourselves and life. For example a star might burn for many millions of years, but eventually it also must end. Therefore it can be seen that the celestial bodies are also limited.

Since the universe is considered to be the sum of all celestial bodies, and all celestial bodies are limited, then the universe can be called the sum of all limited things and must itself therefore be limited.

Some people however, argue that the universe is infinite but, 'reason' (as will be seen in more detail later), science and mathematics rules out this possibility.

One can argue that if the universe were infinite, there would be an infinite number of stars in the sky and the infinite amount of light radiating from these stars would make the night sky white instead of black. Since we see such large amounts of black emptiness, the universe must be composed of a finite number of celestial bodies.

The objection to an infinite universe was raised in 1823, by the German philosopher Heinrich Olbers, who also pointed out that the light from distant stars would be dimmed through absorption by intervening matter. However, if that happened the intervening matter would eventually heat up until it glowed as bright as the stars, this problem with an infinite universe has since termed 'Olbers Paradox'.

There is another problem with an infinite universe, which also gives rise to a paradox. When we observe systems within the universe, we notice that they involve irreversible physical processes e.g. We observe that a system will under go an irreversible process in a finite time like the burning of a candle, burning of a star or the scrambling of an egg. In an infinite universe all physical systems will have completed those irreversible changes at a finite rate an infinite time ago. If this were the case we would not be observing these processes now.

That fact is the universe is full of these irreversible processes, which give rise to 'Arrow of Time' to the universe. The investigation of thermodynamics and irreversible processes will be studied in depth later in the book. Suffice to say it is not an argument put forward by many scientist today.

If we follow the reasoning that humanity, life and the universe are all limited, we can now proceed to ask how and why they all came into existence at all. Of course most scientists today will claim that the universe sprang into existence from a 'Big Bang' many billions of years ago, and that all the material of the universe came into existence out of nothing, spontaneously by chance. This theory of the 'Big Bang' as described by many scientists, is very interesting, as it consists of a long series random accidents that eventually lead to the formation and origin of life on earth. The evidence of the Big Bang Theory will be examined more closely shortly.

The Big Bang Theory still leaves the question **'Why?'**, unanswered, and at this point, most scientists will cough and excuse themselves from the room, while others will argue that this is a question only for philosophers and not the domain of pure sciences.

[6] Used in the context of the 'human race' or a human being as this is the convention

However If we continue with our line of reasoning from earlier, where we demonstrated that the universe is limited and all that is within the universe is limited, we can further reason that anything that is limited is unable to exist by itself, and must therefore be dependent on something else. This is true because there is nothing that we observe in this limited universe that does not depend, for its existence, on something else. For example as human beings we are dependant on food, water and oxygen. We would die without the required amounts of these essentials for life. All things in the universe can be observed to be similarly dependant, even the stars and galaxies. The sun is dependant on its supply of hydrogen which it uses in a continuous thermonuclear reaction to produce helium and other elements. Without this supply of hydrogen the sun would 'die'. So we can also say that everything in the universe is by definition not **eternal** and **self-subsisting** but. limited and dependant.

We now arrive at a cross-roads, we can now rationally deduce one of three possibilities for the origin of the universe:

1. The universe depends upon itself for its existence, having caused itself to come into being.

2. The universe being limited depends for its existence on something else, which in turn depends on still something else ad infinitum.

3. The universe being limited depends for its existence on something else, which itself is eternal, infinite and self-subsisting.

To decide which of these possibilities is the answer to our question I would like to quote a statement of the master detective, Sherlock Holmes, who said something to the effect of:

> *"How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth"?*

What Mr Holmes meant by this, can be illustrated by a famous lateral puzzle I heard when I was in school.

> *"A boy and his father were driving back home from a football match, when suddenly, a truck pulled out in front of their car. The father slammed on the brakes... But unfortunately they crashed.... The father died instantly and the boy was very badly hurt. Ambulances arrived shortly after and carried the boy to the nearest Hospital....As the nurses began preparing the boy for immediate surgery, the surgeon arrived in the operating theatre. Upon closer inspection of the boy however the surgeon gasped and said 'That's my son!!'.....".*

How is that possible? Most of us in my class came out with suggestions like, The surgeon was mistaken, the man in the car was only a foster father, the surgeon was the grandparent or the surgeon was just using a figure of speech.

If you stop and think, those of you who are not quite 'on the ball' and haven't already figured it out, eliminate all the impossibilities, and what are you left with? Well, if the father is dead from the crash, that can only leave.... the mother of course.

Because most of us make the assumption that the surgeon must be a male, the thought that the surgeon could be the mother is far from our minds, so instead we search for an alternative answer.

Similarly, just to further illustrate the point, imagine three people were outside your door, about whom you knew nothing except one was called John, one was called David, and the other was called Harry, although you did not know who was who. If two of them entered and introduced themselves as David and John, you could very easily identify the person outside as Harry, even if the voice of that third person was female.

Returning back to our universe, we can similarly eliminate two of the possibilities.

The first possibility cannot be accepted because we do not observe anywhere in the universe anything that has the possibility of coming into existence by itself from nothing. The second possibility does not answer our question of ‘Why?’ but rather puts off giving an answer, and we will come back to look at it in more detail towards the end of the book.. The third option which. remains after we have eliminated the first two, states that a supreme being or Creator is the cause behind the existence of the universe. Furthermore it can be rationalised that this Creator must be completely independent of the universe, although the universe is entirely dependent upon Him[7]. This rationalisation of the Creator will also be explained in later chapters.

Of course most of you will not accept the third option without a deeper investigation and more evidence. It is with the intention of providing this evidence that I will now proceed.

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[7] To those who may wonder at my assumption of a masculine gender for the Creator, even though in my examples I showed we should not assume the doctor was male. I use this convention simply because I think it is more elegant than politically correct he/she or him/her convention used by some writers and not for any male chauvinistic reasons, for as will be seen later the concept of gender which is a physical attribute cannot be applied to a Creator

PART ONE

What has gone before

"It has long been an axiom of mine that the little things are infinitely the most important".
A Case of Identity

To fully grasp an understanding of the origin of the universe, we should investigate the past to unravel how our understanding of the universe and life has evolved over the centuries.

Chapter One

The Dawn of Science

"Ancient Man had nothing but his hands and wits to grapple with the problem of how to live from day to day. There was no store of previous human experience upon which to draw....."
Sir George Dunbar

As our scientific and archaeological research digs deeper into the oblivion of the measureless past, increasing knowledge adds to our respect and appreciation of the advancements we have made in science. We see as Man came to terms with the concept that his well-being was wedded to his ability to conquer the changing elements of his environment, to foresee and exploit them to his advantage in a harsh and competitive world. He did not view this world as an external entity. Rather, it was alive with the passions and personality that he saw within himself and his fellow humans. Likewise, his personal feelings and experiences took on a cosmic significance. Everything was inhabited by a personal spirit. The world was only a manifestation of his own mind. There were no inanimate objects. Dreams were as real as rainstorms. All phenomena possessed a multitude of different intrinsic meanings of the sort that we would now associate only with symbolic representations of them in art, sculpture, or poetic diction. Man did not seem to view himself as distinct from Nature.

Our experiences of modern interest in the occult are merely as distant spectators, not as true participants. We cannot appreciate what it must be like to live immersed in a world that is viewed as entirely magical.

Although our earliest records indicate an intelligent Man with well-developed languages and established repositories of **previous information**, Man, like the beasts, could also learn the hard way by the consequences of experience. Gradually, as he noticed daily and seasonal regularities, he was able to recognise those appearances that always seem to follow from others.

He discovered that events do not all arise in an unconnected and arbitrary manner, but exhibit a degree of predictability that could be exploited to some advantage. He learnt to simulate the results of his possible future actions by **thinking** about them. If the result of some behaviour was foreseen to be adverse he could avoid it. He no longer needed to learn solely from the consequences of his mistakes. He had passed from experiencing the world to thinking about it.

From the discoveries of anthropologists we have learnt which presuppositions were shared by primitive cultures. We observe that Man has always possessed certain organic needs and instincts, some of which are common to all animals like the procreational instinct or the survival instinct. But one instinct is unique to Man alone. This is mans innate spiritual instinct. It is this instinct which causes Man to venerate and worship that which he believes is greater than himself. This instinct leads to a nascent belief in the uniformity of Nature, and in the succession of cause and effect.

These words have a familiar modern ring, but their emergence was through the practice of magic rather than scientific experiment. At first such a consequence appears strange surely, if magic is a focal belief then one must believe that anything can happen? But this is not necessarily true.

Dancing the rain dance brings rain, sacrificing to the fertility god brings an abundant t harvest, and feting the god of war brings the defeat of your enemies. Through such simple formulae there is displayed a real belief, however misplaced, toward the idea of an orderly and predictable world in which certain acts invariably create particular effects. In such mythopoeic cultures there was complete determinism. Nothing happened without a cause and a reason; everything had an interpretation. The concept of chance could therefore not arise.

The concept of cause and effect in Nature as the consequence of some set of impersonal laws, is foreign to primitive cultures. Because there was seen to exist no separation of the personal and the subjective from the things of Nature, all events were ascribed to wilful acts by something or somebody - for example, these were attributed to the outcomes of conflicts between opposing forces of good and evil.

Where we are content to view a single isolated event in the external world as possessing a cause and an effect, the primitive mind saw everything interwoven into a tapestry which was expressed by a story. Rather than analyse events into the particular, they sought to fit them satisfyingly into the whole.

This exercise is the forerunner of what we call abstract thinking: the manipulation of signs and symbols in a self consistent logical fashion according to certain rules. One further difference in emphasis for Man in his approach to cause and effect in Nature was the focus upon the idiosyncrasies and peculiarities of Nature, where we would look for the regularities.

To the modern meteorologist the pertinent question is 'why does it rain?', but to the primitive mind it was 'why is it raining here and now'. This is what matters when events are only experienced, and not studied. Man was a participant in Nature, not an observer. It was the Greeks who would introduce the idea of 'theory', a concept derived from the practice of thoughtfully watching, rather than competing at the Games. It is the derivative 'theatre' that retains the true meaning in modern English. Man was an actor in a cosmic drama, and the whole world was his stage.

Magical ideas are not easy to overthrow. How do you falsify the idea that some ceremonial invocation of the rain-god's services causes it to rain? If the rains do not come then either the ceremony was wrongly performed or it was overridden by some more powerful magic. Why? Because your witch-doctor tells you so. Magical views of this sort divide a community into two groups: the inner ring of those initiated into the arts of interpretation and the occult techniques, and everybody else.

All the second group can do is wonder how the others do it. It is very difficult for anyone to say that 'the Emperor has no clothes', and even harder to have any reason to want to. Early tribal cultures also appear to have shared another type of presupposition that we do not: the notion that things which have been in tactile contact with each other on one occasion will thereafter retain some vital relationship.

This is a natural view to hold if one believes also in a completely animated world of warring spirits. If you meet somebody, do you not retain some impression of the meeting?

This impression influences your future thoughts and behaviour. As a consequence, is it not natural to believe that objects, or even people, can be controlled by manipulating things that either resemble them or have previously been in physical contact with them? These artefacts were not viewed as symbols of the person from whom they were taken - they were the person. If the first of these ideas had its origin in the observation of kinship and herding instincts amongst humans and animals, then perhaps its residue remains in our debates as to the relative importance of inherited and acquired human abilities.

The belief in the possibility of exercising control over others by building effigies of them, which usually contain a piece of hair or some other part of their body, still exists in certain quarters of the Caribbean where voodoo practices survive. (This idea is the original meaning of our term 'jinx'; to put the jinx on someone was to bring them misfortune by this means). It hints at the idea of simulation which modern scientists use so successfully.

Often one builds a 'model' of some part of Nature, whether it be in the form of mathematical squiggles on a piece of paper or an electronic recreation of its behaviour in a computer. This simulation enables us to derive understanding and control of the real thing. It is significant that the primitive belief reveals the idea that a part of something contains the essence of the whole.

These speculations are of interest simply because magic was one of the forerunners of modern experimental science. Even by the eighteenth century so great a scientist as Newton still possessed strange magical notions which seem totally alien to us when laid alongside the Newtonian mathematics and physics which we share. But Newton saw his work, whether it be in mathematics or optics, alchemy or biblical criticism, as part of a single enterprise. This juxtaposition science and religion provoked Keynes to write:

> *"Newton was not the first of the age of reason. He was the last of the magicians, the last of the Babylonians and Sumerians, the last great mind which looked out on the visible and*

intellectual world with the same eyes as those who began to build our intellectual inheritance rather less than 10,000 years ago". **Keynes**

What is regarded as magic changes with time. To a person of the Middle Ages, the technological achievements of modern science would not be indistinguishable from his idea of magic? Yet it would be wrong to argue that magic was simply the forerunner of modern experimental science. The practice of magic was indeed a form of experimental technology but it was born of a belief that is alien to modern science - that the natural course of Nature had somehow to be altered or perverted in order that power over it or over other persons could be obtained. The ancient practice of magic implicitly recognised a natural way of the world governed by what we might call 'laws' because it sought always to reverse it. It had to call upon evil spirit to oppose the good. This is reflected in the fact that so many occult practices emphasise the inversion of the natural order - recall the 'black mass' in which the Catholic mass was chanted backwards.

For these unnatural practices to be efficacious they had to be performed with the right mental attitude. Modern science does not seek phenomena that respond to the state of mind of the experimenter, nor does it recognise the possibility of somehow breaking the natural order of things.

Such an idea makes no sense within the framework of modern presuppositions, for the natural order is nothing more nor less than the set of all events that can or do happen.

The scientific view aims, as much as possible, to explain phenomena through a single logical principle. It seeks to avoid the magician's division of the world into 'ordinary' everyday phenomena governed by one set of laws, separate from an extraordinary, occult world governed by a different form of law and logic: one that it was believed could be influenced and conjured up by the intensity of the human will.

Chapter Two
The Impact of Religion

"To someone who could grasp the Universe from a unified standpoint the entire creation would appear as a unique truth and necessity". **J. D'Alembert**

A picture of the Universe as an ordered state, subject to rules and regulations introduced for human well-being, owes something to the development of civilised societies possessing a strong form of central government which occurred at many times and in diverse places. This had an indirect influence upon the presuppositions which underpinned the development of science.

Practical necessity, dictated by the collective needs of large societies whether for agriculture, navigation, or the provision of military defence, motivated many scientific investigations.

In the West the scientific enterprise seems to have evolved most successfully in an environment in which there existed a strong belief in the role of law and order in the widest sense. Two possible situations immediately present themselves: One in which the state had a strong civil legal system and central government, and the other cultures in which there existed a strong monotheistic religious belief. The former allows an analogy to develop between the ordered working of Nature under the jurisdiction of natural laws, and the ordered running of society according to civil law. The latter fosters a belief that Nature is governed by the decrees of an omnipotent and Divine Law-giver. A culture displaying both of these attributes is an especially advantageous environment for the emergence of a firm belief in the 'Laws of Nature', and in the rationality and ordered character of the world: a firm belief that there exists something worth investigating.

However it is more significant to recognise that there was a gradual metamorphosis away from the early belief in laws as arising from the intrinsic character of the thing that they controlled, toward the view of the early monotheistic cultures that laws were imposed upon Nature by an external Law-giver. In the Greek setting we shall find this metamorphosis going hand-in-hand with the rejection of teleological modes of explanation in favour of those based upon causal ones. This turn towards the notion of imposed law is pregnant with ideas that transcend the scope of the idea that 'Laws of Nature' are merely the observed habitual successions of events. It emphasises a common factor behind Nature and establishes Nature's universality.

More importantly, it establishes the invariance of some element of Nature in the face of the flux of events. If the laws governing the motion of stones arise from intrinsic properties of each stone, then different stones may move differently, and the same stone may alter its dynamic behaviour as it weathers and changes its appearance.

There is no constant factor in Nature, and there could be no unchangeable laws. We should, therefore, examine how the idea of imposed laws were nurtured by the great monotheistic traditions. In general, for the ancients, the idea of 'Laws of Nature' were different to what it is conceived to be today. For the modern scientist, the most useful sort of law is a set of rules, usually enshrined in mathematical equations, which specify how something changes - either with the passage of time, or as it moves from place to place, or both.

Yet for the Greeks, it meant something that does not change: an immutable, static and perfect harmony. Often, as we shall see, we can still show that there is a close link between any set of equations which describe change in time and space, and some unchanging harmonious symmetry. But the symmetries involved often turn out to be extremely abstract. The biblical view is important because it exerted a powerful influence during much of the period when science grew into its modern form in the West. The majority of leading British scientists, until the beginning of the twentieth century, were devout Christians. We shall detail how this had a particular influence upon their scientific work.

It may be asked here: Why did the Jews not have any scientific interests during these early times? The fact that they never developed any seafaring tradition may be a significant factor. Such a neglect avoids the need to indulge in any systematic study of the heavens for the purposes of navigation.

A long period of nomadic existence and continual skirmishing with neighbouring countries must also tend to stunt technical progress. There is motivation for neither architecture nor industry. Life remains tied to agriculture and tradition. Work is necessary and sufficient to produce the daily bread; life is too hard for there to exist the luxury of enquiry for its own sake. For those without the worry of poverty only Solomon is recorded as taking a detailed interest in the natural world, but his motivation appears to have been more lyrical than 'scientific'.

Clearly astrological inclinations are two-edged.

On the one hand they led some ancient cultures to study the heavens and make detailed records of what they saw there, but on the other hand there always stood the interpreters who resisted any inclination to view things in a new way, since that would amount to introducing a new religion.

Over long periods of time such a belief-system tends to become complicated and contrived, every new observation being fitted into the existing plan no matter how ill the fit, for the real role of the belief-system is to maintain social divisions between those who know how to interpret the heavens and those who do not. Not until there exists a universal and precise mathematical language, can it be possible for absolutely anyone to take part in science.

Chapter Three

A Chinese & Egyptian Heritage

"There is no confidence that the code of Nature's laws could ever be unveiled and read, because here was no assurance that a divine being, even more rational than ourselves, had ever formulated such a code capable of being read". **Joseph Needham**

To argue that the development of a strong faith in the 'Laws of Nature' and the possibility of scientific investigation of the world is facilitated by monotheistic religious beliefs divorced from Nature, gods and astrology, is one thing, but could it turn out that the absence of such ideas would prevent the development of natural laws?

It is not possible to answer this question with any great certainty. Yet, there is one interesting and well-documented example. It appears that the idea of a single supreme Deity was foreign to the early Chinese, and as a consequence the fate of natural science in that culture was a curious stillbirth. For the Chinese there existed no concept of a divine being who acted to legislate what went on in the natural world, whose decrees formed inviolate 'Laws' of Nature, and who underwrote the scientific enterprise.

Despite sophisticated technological developments in rocketry, printing and the widespread use of magnetic compasses in their sailing ships, these inventions provoked no urge to explore natural regularities or the geography of the globe. Their introduction failed to foment periods of revolutionary scientific change and enlarged intellectual horizons, as they did in Western society during the same period.

A central idea of Chinese thought from earliest times until the present era, appears to be that of the spontaneous development of order in the world.

This notion could have had its roots in observations of the natural world, for example of floral patterns, or the purposefully organised collective behaviour of insect colonies.

In these examples there arises a mysterious harmony between many separate parts without external human interference. Alternatively, we might find its roots in the gradual appearance of social order within small peasant groups who found themselves 'naturally' evolving a stable and organised way of life within their communities. This was without the imposition of rules by some external central government. Rules arose by negotiation and compromise rather than dictatorial decree.

There were two dominant systems of thought and conduct indigenous to the Chinese. Confucianism arose in the sixth century B.C.E partly in reaction to the destructive social chaos that existed which was sustained by continual civil warring. The followers of its founder, Khung Fu Tzu ('Confucius' is the Latin form), laid great stress upon the importance of correct and just social behaviour, together with the intuitive etiquette and custom that leads to the right-ordering of society. In complete contrast, their later opponents, the Taoists, were interested primarily in the order displayed by Nature, and stressed it above all the unity of the natural world, and its independence of all the human standards of behaviour so valued by the Confucians.

Confucianism eventually attained official status, and developed into a paternalistic form of liberalism. It was responsible for engendering a view of the world that did not seek rules for the behaviour of nature in logical analysis or through systematic observational studies, but looked instead to the analogy with the harmonious social customs that evolve out of collective human activity. These cannot be predicted. They contain spontaneous and intuitive aspects that could only be arrived at by constantly ensuring that one was co-operating with everything and everybody in the proper fashion. They are simply too complicated to be predictable in practice.

This Confucian liberal ideal, that society should be ordered spontaneously by good and harmonious customs, was called *Li*. It was a foil to the contemporary legalist philosophy that society should be governed by the positive legal dictates, or *fa*, of some supreme ruler or judge, rather than by these less precise natural constraints that everyone intuitively shared. We would today term this 'natural justice' - that lowest common denominator of feeling about what is right shared by most members of a stable and homogeneous society.

For the Confucians, the principal role of the civil ruler was to provide an impeccable example for others to follow. An order arrived at spontaneously by mutual human interaction and common consent was considered greatly superior to one imposed from outside by some external force. There was not that great respect for positive statute law that has traditionally existed in Western cultures.

If an edict of *fa* was found to run contrary to what society regarded as *Li*, then the former was regarded as undesirable[8]. *Li* operated across the entire spectrum of life; it was the reason for the motions of the moon and the stars, for the successful exercise of self-control in human dealings, and for the social divisions of rich and poor. It was 'the greatest of all principles'.

In all these realms, what we in the West might have called 'laws' of Nature were supposed to emerge gradually but quite spontaneously, and to persist as manifestations of stable and orderly behaviour arranged for the mutual benefit of everyone and everything.

The Taoist tradition opposed this search for the order of Nature in social behaviour. It arose through the influence of nomadic magicians and their disciples. In reaction to other philosophies of life the Taoists retreated and lived as recluses outside the milieu of society. They believed that only by being at one with Nature could the order within it be understood. Man and his idiosyncratic customs were unessential in this quest to commune with Nature. The order they were seeking, the Tao (the 'Way'), did not admit of a precise definition; it was beyond our understanding and arose as an equilibrium of the mysterious interplay of opposites.

Again, the emphasis was upon the spontaneous ordering that arose through the holistic interplay of all of the constituents of Nature. This holistic view also denied a clear-cut notion of an external world of physical reality, because we are ingrained into the harmony of Nature in a way that is essential to the order of the whole. To begin a study of Nature creates a problem of self-reference. Laws are latent within things, not imposed from without.

The magical background of the Taoist tradition was a motivation for experimental' practices, however, the Confucian scholar was an aristocrat who looked down on manual work and anything akin to the experimental investigation of the world. Yet despite their technology, the Taoist philosophers never framed any statements that we might call 'Laws of Nature'. They had no confidence in the ability of reason to unravel the Universe, or in the existence of a created order to be uncovered by investigation, and ultimately no faith in the intelligibility of Nature. Their liberal view that the Tao could not exert any coercive influence over Nature, and their theology of pantheistic naturalism, ran counter to the entire concept of a God or controlling the Universe.

The unusual results of these philosophical traditions have been highlighted particularly by Joseph Needham's extensive investigations of the history of science and technology in ancient China. The Chinese world-view appears to have stifled the development of science within this great culture. The evolution of harmonious customs in both the social and the natural realms was seen as arising from the intrinsic character and dictates of each member working for the good of the whole, rather than by the decrees of any external Supreme Being. There was no evolution of the idea of an analogy between civil legislation and ordained constraints upon the allowed workings of Nature, and no tradition of belief in any sort of supreme legislator or omnipotent Creator.

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[8] Read the 'Judge Dee' mysteries' written in the 1950s by Robert Van Gulik. These trace the career of a Confucian judge in sixth century China from his first appointment as a local magistrate to his experiences as Lord Chief Justice and Regent for the Emperor when Peking is stricken by plague. Van Gulik was a Dutch diplomat and an accomplished oriental scholar who based these mystery stories upon real cases that arose in ancient China-suitably embroidered by the story-teller's art, retaining a traditional Chinese literary style (although mercifully he does depart from their tradition of revealing 'who-dun-it' at the beginning of mystery stories rather than at the end), and immersing the reader in a complete recreation of everyday life in ancient China. These stories are used as background reading in many degree courses in oriental studies as an entertaining and accurate introduction to the ambience of everyday life in early China. Some of the best have recently been republished in special editions for that purpose by the University of Chicago Press.

Everything had the ability to bring itself into being, and so there was no psychological desire to introduce a personal Creator.

Thus, it has been suggested that the emphasis upon *Li* rather than the more Western tradition of *Fa* suppressed the notion that Nature followed definite laws laid down by God, and gave the early Chinese no reason to believe in an underlying rationality in Nature that might be uncovered and understood by detailed observation and codification. The Universe was believed to be far too complex for such an enterprise to be even considered. This holistic view would also deny the idea that by studying Nature on a small scale, piece by piece, one could arrive at an understanding of the whole. Nature was all of one piece, every part playing its part in a huge self-consistent pattern, yet each followed only the influence of its own intrinsic compass - a society of ants rather than one of men!

The idea of order, never carried with it any implication that there must inevitably exist constraining laws and an ordaining Law-giver. Despite their early technological superiority, the scientific attitude faded and died unfulfilled in ancient China because the notion of the **'Laws of Nature'** never arose**.**

The Egyptians some 3000 years Before the Common Era (B.C.E.), that's about 5000 years ago in real terms, first became interested in the heavens as they began to settle the fertile land around the Nile. Although most of their interests for astronomy were based on religious rituals and they had a great interest in the seasonal calendar and began to use the constellations to determine the time of year, for activities like sowing seeds and harvesting.

Archaeological sites have revealed that the Egyptians had developed the study of medicine to a high degree. The evidence of successful brain surgery, and the writing down of simple remedies to certain illnesses have been found, and a great detail on herbs and spices used in the process of embalming of mummies. The degree of success the Egyptians had achieved in preserving the bodies of the dead from decay, is testified by the numerous mummies discovered fully intact after several thousands of years.

However due to all this background of religious preoccupation the Egyptians did not have much chance to develop any real progress in the fields of cosmology.

The Egyptians had many different myths and legends as regards the universe, worshipping and venerating that which sustained their daily lives, like the sun god Ra. They believed that Ra, was the sovereign lord of the sky and during the course of the day took a boat ride from east to west.

Most will agree that the greatest achievement of the Egyptians, is the building of the Great Pyramids.

However the building of these pyramids and their unique structural dimensions, give rise to many mysteries. It is believed that the Egyptians had stumbled across the mathematics and geometry by trial and error, which the Greeks later logically deduced in their theorems and axioms.

At about the same time on the other side of what is now commonly referred to as the fertile crescent, in the valleys of the Euphrates and Tigris rivers, the Sumerian civilisation had begun to use the earliest recorded form of writing. Over the centuries the region became the centre for a number of successively dominant empires. It is here the study of the stars lead to the birth of the earliest astronomers. Steeped in religious ritual the study of the heavens became very intense, and stars and planets began to be regarded as more than just a seasonal calendar. Star catalogues dating to 1800 B.C.E. have been found, from which it was possible to make many astronomical predictions, such as eclipses and the conjunctions of celestial bodies.

Others later also began to look up into the sky and notice the orderliness of the sun, moon, and celestial bodies. They observed how certain events on the earth were synchronised with celestial activities, like the change of the tides and the phases of the moon. One such group of people were the Druids of southern England, who built the famous Stonehenge. This strange collection of stones was used by the druids to calculate the exact movements of the sun, which they worshipped. They were able to predict events such as the vernal equinox and summer solstice.

These would-be astronomers however got side-tracked by their religious beliefs, much like the Egyptians, and from astronomy developed astrology. The extent to which astrology was relied upon in these ancient times is evident from the vast records of astrological reports of various kings found in archaeological excavations.

Very little changed by way of advancement in observations of the sky until the Greeks and Chinese came on the seen. It was at this time that astrology became formalised into what we know today as the Zodiac and horoscopes.

Chapter Four

Influence of The Greeks

"The real importance of the Greeks for the progress of the world is that they discovered the almost incredible secret that the speculative Reason was itself subject to orderly methods."
A.N. Whitehead

The Greeks marked a turning point in the history of cosmology. For the first time many people began to look at the celestial bodies for reasons other than astrology. This allowed the Greeks to develop their philosophical ideas, and produced a climate conducive to satisfying the intellectual curiosities of life and the universe

The great emphasis on the search for 'absolute truth' in the activities of numerous Greek philosophical schools witnesses for the first time a systematic desire to seek out and comprehend the truth for its own sake, divorced from any military or practical stimuli, or from the acquisitive desire to amass a vast panoply of facts. Surely this is the seed from which the tree of knowledge grows?

The reasons for the failure of the Greeks to develop a fruitful notion of the 'Laws of Nature' and embark on their systematic discovery are manifold, and their mutual inter-relationships complicated. Nonetheless, we can isolate a number of dominant trends in Greek thought and practice that collectively appear to have erected a barrier through which their thinking about the natural world could not pass.

Let us begin with some of the general trends that were present during that period from about 600 B.C.E[9] until Aristotle's death in 322 B.C.E, during which all the significant philosophical developments took place. Later, we shall pick up on the individual biases of particular, influential schools of thought. The most striking general feature to be found is the extent to which what we would now call 'science' is a subculture within philosophy. Indeed, there existed no distinction between what we would now term 'science' and 'philosophy': there was only a general inquiry into the nature of things, a natural philosophy.

Before Aristotle's influence there did not exist any organised division of this inquiry into different subject areas. The principal distinction that did exist was between the array of natural things, which displayed change and complexity, and the static and absolute truths which were of a mathematical type, were epitomised by geometry. Groups of thinkers were linked by their connection to a particular school of thought, their thoughts about natural phenomena conditioned by the dominant in-house philosophical line. It is as if departments of physics in universities today were run by leading philosophers of varying persuasions.

At the University of Brummage the idealists might hold sway, and attract colleagues and visitors who toed this line, while at the University of Slippery Rock everything would be done in strict accord with the dictates of the operationalists. Science would become natural philosophy in the worst sense (this is not to deny that there are parochial influences in modern scientific work, and 'centres' where a particular school will research the consequences of a particular theory, or work in a particular style set by their leader; it is just that these modern schools of science are not shaped by philosophical views concerning the entire spectrum of human enquiry).

This philosophical umbrella over investigations of the natural world was, as we mentioned earlier, initially vital if problems and phenomena were to be discussed rationally, but the goals of the early philosophers were, in retrospect, far too ambitious. The Greek philosophical schools were interested in ascertaining the whole and ultimate truth about the world. Their focus was always upon the general rather than the particular. This ambition has one very unfortunate effect: having begun with theories about the nature of everything, it is very difficult then to proceed to detailed theories about particular things.

[9] Dates are based on the notation B.C.E - Before the Common Era (not B.C) and C.E - Common Era (not A.D)

A theory that can tell us something about everything will, by its very generality, be too vague and diluted to tell us very much about anything in particular. Science only began to make dramatic progress during the Renaissance when it limited its objectives, and started to address the particular as the necessary prerequisite to any understanding of the general. Whereas today scientists may disagree about explanations for the different things that we see in the Universe, they are agreed upon the subject areas for study.

But for the Greeks the term 'nature' had many different meanings, and their philosophers preferred to argue about the meanings of the idea rather than observe what happened in the world.

There was another unfortunate emphasis in the quest for the ultimate nature of things that dominated the work of the early materialist philosophers. Although they were the only Greek philosophers to believe that things could be understood from the evidence of our senses, rather than depending on some higher form of reality and truth that is not accessible to the senses, the things they applied this logic to, were totally beyond the reach of observation. Questions like the origin of all things, the origin of life, and so on. Their materialistic reductionism led them to take the view that, if all things were made of air or water, then the properties of anything from a mind to a mallet could be entirely explained by knowing the properties of air or water. Later, both the Platonic and Aristotelian viewpoints were a strong reaction to these notions; they held that ultimate reality was something totally immaterial and accessible only to pure thought.

The predominance of the philosophic attitude led to another superficially positive feature becoming a snare. The emphasis, in particular that of Aristotle, upon formal logic as the paradigm to be emulated by all reasoning about nature creates sterility. Formal logic is admirable in mathematical argumentation where one is interested in finding unusual connections between types or numbers, or the relationships between the lengths of the sides of triangles.

It allows a network of deep interconnections to be set up between things that one already knows. It shuffles and relates things that are already defined. But logic alone cannot reveal to us the existence of new types of entity. And of course, it has little use for experiment or observation.

A reverence for geometry fosters a belief that the most important properties of the world are static, and prevents one focusing upon the dynamic aspects of its structure. It reinforces the Greek attitude that what is important is what things really 'are', rather than how they behave or how they are related to other things.

A scientist who uses only logical reasoning from 'self- evident' principles will soon find himself in a cul-de-sac-like a blind landscape artist. For our knowledge of the workings of the natural world to progress we must be opportunistic.

We shall see in a later chapter that science owes a remarkable and mysterious debt to mathematics, but the Greeks were to some extent impeded by their very reverence for its inexorable logic.

Greek mathematics was unashamedly pure mathematics. It introduced the use of 'axioms' to represent truths that were regarded as self-evident and unworthy of demonstration. They realised that analysis had to have a beginning. The advance of applied mathematical thinking was coupled with a sociological bias that, in retrospect appears as a major impediment to the development of science within their culture.

The Greeks had a low view of manual labour. They were a conquering civilisation and slavery was a key element in their economy. In some communities we know that there existed more than one slave for every two free men. These inequalities within their society created a great division between the intellectual and the practical world. The result was a society devoid of technological progress. Some have argued that the presence of slavery within a society removes the stimulus to look for labour-saving devices, and is sufficient to explain the absence of any systematic technological progress in that direction by the Greeks.

Although this is an argument that could be true about some societies, it is not very persuasive. Did not the Egyptians and other great empires of the ancient world use slave labour, but advantageously harness it for their technological projects? It is more likely that the existence of a slave labour force will serve to encourage vast technological projects like the construction of the Egyptian Pyramids. For the Greeks, the effect of slave labour was indirect and psychological. Manual work was what slaves did. It was mundane. To make devices and to experiment, was beneath the dignity of the aristocrat; it was an activity to be pursued by those who could not think. The results of such a high-minded prejudice are unfortunate.

To seek the truth for no other reason than to know it is admirable, but if it leads to the view that a search for the truth for some other reason is inferior, then it becomes a snare.

The result of this mentality was that all concern with Nature was dominated by theory. There was no experiment. The study of Nature was very much a spectator sport. It was literally the activity of the 'theoretician' who sat in contemplation of the activities of the competitors in the ancient Olympics. He was the one sent to bring back the revelation from the Oracle at Delphi. He did not participate, nor did he dig out the facts for himself.

The subscription to a slave labour force does have one direct practical consequence for the development of applied science.

Although it could, if exploited correctly, accelerate the progress of vast architectural or engineering enterprises, it hinders the development of a large pool of independent skilled craftsmen within a society.

From the workshops of such individuals, and by their motivation to manipulate Nature to build bigger and better artefacts and tools, did the practice of applied science receive its stimulus during the Renaissance. There appears to have been more to this early Greek aversion to experiment than a distorted sense of values.

Although Greek thinkers did not appeal to 'nature gods' to provide explanations for the phenomena they witnessed around them, they retained inhibitions ingrained into their culture by previous mythological beliefs. Nature was not entirely secular, and the idea of manipulating it in order to learn things would have seemed peculiar. It was a living organism, not a mechanism. Their philosophy was 'Understand the world by all means, but do not try to alter it or use it for mundane purposes'. It is probably no accident that most Greek scientific progress was made in astronomy, where no manipulation of Nature is possible. Moreover, the Greek gods - an impetuous and moody lot - did not encourage the idea that the workings of Nature were dictated by a universal and divine decree. There were many gods, each with his own area of jurisdiction, and they inhabited a world in which decisions were made by argument, negotiation, and compromise rather than omnipotent divine decree.

The mythological basis of their earliest ideas about the world perhaps had another important consequence for their scientific method - it ensured that there was little emphasis upon experimentation. Many of the physical theories and cosmologies of the Greeks read like rational revisions of the early myths. They are invariably stories and explanations of what had happened in the dim and distant past. They were not hypotheses or predictions about the future.

All that was required of them was the absence of internal contradictions. They were exercises in deductive ingenuity; the question of observational consequences in the future never arose.

The founding of schools and academies for the promotion of discussion and inquiry had many obvious positive benefits. For one thing it provided thinkers with critical colleagues - something that a Copernicus or Galilee was to lack. The informal discussion of conjectures and refutations with fellow scientists of all opinions has become the basis of modern research work. Despite external appearances, the principal function of large scientific conferences today is not the timetable of official lectures around which the meeting is framed, nor even the texts of those lectures in the published proceedings, but the bevy of informal conversations and arguments that abound in the hectic conference atmosphere.

Most take place in hotel lobbies, on trains or coaches en route to the lecture hall, over lunch or dinner breaks, or in small informal groups meeting over coffee.

Yet, we have seen that the collective behaviour of the Greek schools also had a detrimental effect because of the overriding role played by the allegiance of different schools to particular philosophical systems. Another bad side - effect, best illustrated by the practices of early pre-Socratic groups like the Pythagoreans, was a curious desire for secrecy. They were secret organisations in the way that the Freemasons are today. In around 531 B.C.E, Pythagoras of Samos had founded a monastic brotherhood in which the philosophical beliefs of the school dictated their way of life on an everyday basis.

Today we would call such a thing a cult religion. Indeed, it possessed many rules and regulations about daily life that are not dissimilar to the Jewish ceremonial laws found in the Pentateuch. This order lasted for about two hundred years, and was extant during the careers of Plato and Aristotle. Whereas the first Greek philosophers in Miletus had been guided purely by curiosity in their musings about air, earth, and water, the Pythagoreans had a mystical imperative.

They were seeking out the divine harmony of the world in order to become one with it. The Pythagoreans were the first of the Greeks to refer to the world as a 'Cosmos', so emphasising the harmonious order it represented to them.

They believed in the reincarnation and transmigration of souls, and that the elevation of their social status in the next life could be guaranteed by rigorous adherence to their code of conduct in the present one. Eventually the cycle of birth and death might be broken by their sublimation into eternal union with their 'gods'.

The contemplative mood was the highest of ideals in all aspects of everyday life. For example, Pythagoras would have regarded the spectators as a more important component of the Games than the competitors. For the spectators come neither for material gain nor to seek power and status. Of course, Pythagoras' spectating was not just idle viewing. It is an active and thoughtful appreciation of the art-lover looking for beauty and geometrical harmony in a sculpture or a piece of architecture. It involved the mind as well as the eyes.

The Pythagoreans' great discoveries in mathematics and musical harmony are well known today, but the mystical motivation for their investigations in the past had some peculiar consequences. The discovery of irrational numbers in geometry shook the foundations of their beliefs, and so it was for some time kept a closely guarded secret. Their religion of numerological beliefs dictated that observations of the world had to fit in with their ideas of harmony; observation could not serve as the basic guide to the way the world was. For example, Aristotle later wrote of the Pythagoreans:

> *"They held, for instance, that ten is a perfect number and embraces all the powers of number. On this view they asserted that there must be ten heavenly bodies; and as only nine were visible they invented the 'counter earth' to make a tenth".* **Aristotle**

Superficially, the Pythagorean belief that everything was 'made of numbers' is not dissimilar to the modern notion that the Universe is best described by mathematical quantities. But there is a real difference between admitting, as we do, that it is possible to describe the workings of Nature by mathematical laws, and believing, as the Pythagoreans did, that there was something divine about the numbers themselves.

We have found the fruitful idea to be that there are numerical relations between things, but we do not endow the numbers themselves with any magical or sacred status as the Pythagoreans did.

What now seems so strange to us now, is that Pythagoras would not have understood how there could be any distinction between his mathematical ideas and his mystical beliefs about immortality and oneness with the Cosmos. Such is the unbreachable gap between the past and the present. Yet this mystical trend always survived amongst some group of natural philosophers right up until the time of Galileo.

The pursuit of numerology was a rival and an ultimately unsuccessful route towards the mathematization of Nature. Whereas science eventually grew by identifying causes with effects in a mathematical way, the hermeticistic[10] successors of the Pythagoreans sought the inner meaning of Nature through mathematical symbols. But they regarded Nature as an encrypted message which they could divine by insight, rather than a system dictated by externally imposed laws which they could determine to increasing precision by experiment. Their image of Nature as a book to be decoded and read would ultimately be displaced by the image of the world as a machine, in which every event had a cause and an effect rather than a meaning.

In the end, the positive trends in the Pythagorean approach, the use of mathematics to describe the world, and the search for causes of events, were dissipated by their mystical motivations. But the cause of the school's demise was not internal self-inconsistencies; rather, it was the character of the dominant Platonic school of thought that succeeded it, and the way in which it developed earlier Pythagorean thinking about the visible universe.

[10]The so called hermetic tradition derives from fifteen anonymous treatises written in the first three centuries and traditionally ascribed to the Egyptian god Hermes Trismegistus. They are a mixture of mystical and religious writings which include elements of Greek, Jewish, and Persian philosophy and had a significant influence upon some renaissance thinkers.

Chapter Five
The Legacies of Plato & Aristotle

> *"Beauty is a sequence of hypotheses which ugliness cuts short when it bars the way that we could already see opening into the unknown".* **Marcel Proust**

Plato was born into a noble Athenian family in about 428 B.C.E. His contributions to philosophy and literature were immense, but we wish to focus upon just one key aspect of them that impinges upon our quest for the 'Laws of Nature'. Although Plato inherited from the Pythagoreans a respect for the role of arithmetic and geometry in human inquiry, his principal motivations were not what we would call scientific, nor was he trying simply to solve problems raised by earlier generations of natural philosophers. His main interests were in moral, social, and political questions.

Plato introduced a distinction between the visible world experienced by our senses, and a theoretical world of pure 'Forms' or 'Ideas' which were the perfect blueprints of which all that we saw and experienced in the world were imperfect copies. The real truth about the Universe, Plato maintained, was only to be found in this world of the perfect Forms, not in the natural phenomena we observe with our senses, nor even in the mathematical quantities that we have discovered. Matter only existed with a secondary status: to realise the Forms. These Forms were held to be eternal. They would, in some way, have to remain in existence even if the physical universe and observers within it were to disappear.

This notion that ultimate reality was only to be found in things unseen, was implicit in the earlier Pythagorean thinkers as well as in the fragmentary writings of Heraclitus, Parmenides, and Anaxagoras. It introduced a dualism between the real world and an apparent one. Of the former real, changeless world of perfect Forms only a rational knowledge was possible, but there could be empirical knowledge of the constantly changing but imperfect world of our experience. Much of Plato's thinking attempted to relate these two strands.

The realist strand was followed by Aristotle, and developed into practical science. The rationalist and Idealist theme that derived from Plato would one day merge again with Aristotelian empiricism to create the world-view of the medievals, but subsequently they would diverge again. Plato retained the Pythagoreans' strange ideas about reincarnation, for he held that our senses first perceived these Forms in a past existence in which the soul was unencumbered by the imperfections of the body. This precognition enables us to recognise and recollect the versions of these perfect Forms we see in this present incarnation.

Some have argued from this evidence that the Platonic school was an unmitigated disaster for science. It effected a complete divorce between theory and observation. No workman could invent a new device, because he had to wait for the gods to originate the perfect Form on which it would be based. Technical inventors of the past were told that they had merely copied the blueprints of the gods! New invention had to await a sort of divine initiative as though the gods had to declassify ideas before humans could have them.

The idea that some type of natural philosophy should be pursued with the aim of material gain or the saving of labour, rather than as part of the pure search for ultimate truth, would have been unacceptable to Plato's school. Not only was the idea of technology and experiment anathema because of the abiding prejudices against manual work, but it was now being claimed that there was no primary evidence concerning the structure and workings of Nature to be found in sensory perceptions of it.

Modern scientific practice (although not necessarily all philosophical interpretations of science,) is predicated upon just the opposite: the primacy of sensory perceptions, whether they be made by human eyes or by Geiger counters. Thus it appears that Plato's ideas do more than just undermine observation of the natural world: they positively discourage it as a misleading and imperfect guide to that true nature of things which is to be found only by pure thought. But before endorsing such a negative view too enthusiastically, it is interesting to look a little more closely at Platonic Forms to see if we may have missed something rather subtle in Plato's own conception of them.

Plato’s idealism regarding perfect Forms is linked to a type of instrumentalism. He suggests that astronomers should devise geometrical models which ‘save the appearances’, that is which describe what is seen, but make no claim to be representations of the underlying reality. Later, this programme was carried out by Ptolemy (AD 100-178), who adopted the anti-realist Platonic view that his descriptions of the heavenly motions were useful devices for summarising what was seen.

Various different descriptions could achieve this, but the simplest was naturally chosen as the most useful in applications.

The immediate scientific consequence of the doctrine of Ideal Forms, or Platonic Idealism as it became known, was to reinforce the neglect of applied science, and turn attention towards the mystical search for what things really are rather than how they behave. Even if it did possess the vision of ‘Laws of Nature’ as a greater truth than the individual instances of them, it placed these laws outside of the world of observation and measurement.

To conclude our brief discussion of Plato’s influence upon the search for the blueprints of Nature, we should probably agree that the immediate consequences of his introduction of the doctrine of Forms were disastrous for the development of scientific inquiry. Observed phenomena were regarded as misleading.

The ultimate reality was unobservable and immaterial. Undoubtedly there were benefits in such a dramatic development in abstract thinking, and the difference between reality and appearance would eventually be important, but this could not come about until there had been a period of detailed information gathering. Plato was to be succeeded by a philosopher with just such a practical bent.

> *“We are all inclined to direct our inquiry not by the matter itself, but by the views of our opponents; and, even when interrogating oneself, one pushes the inquiry only to the point at which one can no longer find objections”.* **Aristotle**

Aristotle was born in 384 BCE in the city of Stagira, an Ionian colony on the northern Aegean coastline. His father was physician to the court of King Amyntas II of Macedonia, and although both he and his wife died while Aristotle was still a boy, this childhood contact with practical scientific matters seems to have left an indelible imprint upon him.

At 17 he entered the Academy as a student of Plato, and began his studies by composing dialogues in the Platonic mould, rather as modern research students might begin their apprenticeship in research by working out some practice problem or a simple generalisation of a problem solved first by their research supervisor. After Plato’s death he left Athens, probably because he disliked the growing trend towards making philosophical thinking about Nature into a branch of geometry. He did not believe that it was adequate for science merely to ‘save the appearances’ by giving some helpful geometrical account of what was seen. He was a realist who wanted to see theories of Nature taking their place within a wider philosophical scheme of things.

During this self-imposed exile his later interests in flora and fauna began to germinate, but his most famous experience was as tutor to the young son of Philip of Macedonia a teenager who was one day to become known as Alexander the Great. When Alexander took power on his father’s death in 335 B.C.E, Aristotle returned to Athens, and founded a new school of study that became known as the Lyceum.

Within this ancient university he set about the detailed study of everything there was to study. The Lyceum continued in Athens and Alexandria for around 600 years, while its prototype, Plato’s Academy, remained in Athens for more than 900 years. The names of both institutions have coloured education ever since, and the world still abounds with ‘academies’ and ‘lycées’.

Modern scientists have acquired an extremely negative attitude towards Aristotle and his work. Much of this has arisen because he has been encountered, not as Aristotle writing in his own words, but through the dark glass of ‘Aristotelianism’, that labyrinth of thought developed and propagated by the medieval Scholastics. It is this dogmatic Aristotelianism that was to draw such a contemptuous reaction from the liberated scientists of the Renaissance.

Yet, despite all their problems with the institutionalised views of their day, Renaissance scientists like Galileo had the greatest admiration for Aristotle himself as both a philosopher and a scientist. Even in the nineteenth century Charles Darwin regarded him as still the greatest of all naturalists. Undeniably, he has turned out to be the most influential thinker who has ever lived.

Aristotle's influence upon the idea of 'Laws of Nature' is slightly ambiguous. On the one hand he effected a vital change of emphasis towards empiricism after Plato's idealist influence, whilst on the other he introduced a barren way of thinking about the causes of natural phenomena that was to be an impediment to the right understanding of Nature for nearly two thousand years. His writings were to become the supreme and final authority in Western thinking until the Renaissance, and were invested with a dogmatism that he himself, judging by his continually evolving ideas, would have surely found repellent.

Whereas Plato had turned his gaze away from mundane, everyday phenomena, and directed the attentions of his followers towards the imaginary world of perfect Forms, Aristotle was a man of this world. An ardent realist, he was interested above all in the detailed observation of the natural world, and organised the work of his school accordingly.

Botany, biology, geology, astronomy: all these subjects were studied systematically and in great detail. Animals were dissected, and specimens collected and catalogued. Aristotle was engaged in some of these activities personally, whilst others he placed in the hands of his most able colleagues.

To establish these practical studies as important directions of enquiry, and to persuade the most able of his colleagues to engage in such work was quite an achievement. He had inherited individuals steeped in the Platonic prejudice against looking at material things at all, let alone the study of bugs and beetles.

Young students dreaming of putting forward new and grandiose speculations about the ultimate nature of the unseen perfection behind the Universe, now found themselves consigned to digging up worms and studying the internal organs of dead dogs. Indeed, how many professors of philosophy would find such a redirection of their activities appealing even today?

This complete change of emphasis away from abstract, unfounded, theoretical speculation about unknowable things towards the down-to-earth investigation of observed things was a remarkable and vital achievement. Aristotle realised that there was a need for speculation about Nature to be judged by some criterion more rigorous than our ability to defend their logical consistency in philosophical debate with our opponents.

So, given Aristotle's passion for observing natural phenomena, his disdain for the fantastic philosophy of the Platonists, and his objections to the mystic geometrization of Nature by the Pythagoreans, why was there not a scientific revolution?

Aristotle's work emphasised the collection and classification of data, but he was not interested in relating facts together in the way that a modern scientist would seek to do. Moreover, there was no attempt to manipulate Nature artificially by carrying out experiments to test particular hypotheses. Aristotle was not looking for 'Laws of Nature' that codified changes or recognised regularities in the chains of cause and effect. This blind spot was not an accidental omission, but an inevitable consequence of his wider views about the nature of things, and the laws that governed their behaviour.

Whereas Plato had divided things into the appearances and the other-worldly Forms, Aristotle regarded only the observable things of this world as real and worthy of study. But he distinguished between two aspects of the things we see and touch. These he called 'Form' and 'Substance'.

He believed, like Plato, that there were timeless, unchanging Forms, but they were intrinsic properties of the objects in this world, not abstract templates lodged in some great design-shop in the sky. 'Substance' was matter, the stuff that we touch and manipulate, but 'Form' was the specific realisation it had been given, and our minds can elicit the Form within any observable object by abstract reasoning. Form was the thing into which the Substance was fashioned. The difference is clear to us: the Form cannot exist without the Substance that is necessary to express it, and any Substance must have some Form, although that Form could change with the passage of time.

Suppose that we construct a shed in our garden. The Substance may be wood (the word Aristotle uses for ‘substance’ actually means ‘timber’, the usual building material of that time), and will remain so, but the shape and design that distinguishes the end result from a pile of logs is its Form. This Form may change with time as wind, rain, and rot alter the appearance of the shed.

This idea of Form has in some ways influenced our own language, for when we speak of ‘informing’ someone we mean that we wish to transfer some abstract idea into their mind, and we call a collection of such ideas ‘information’.

This information can be stored on different substances today, in the neuro-circuits of our human memories, on paper, on magnetic tape, or on a blackboard. Unlike Plato’s abstract Ideal Forms, Aristotle’s Forms were in things.

This way of thinking led to his distinctive ideas about the causes of natural phenomena. Roughly speaking, Aristotle viewed causes and effects as inherent properties of the things themselves, rather than as relationships between events as would modern scientists. So, for instance, he would view a lunar eclipse as an attribute of the moon rather than as a consequence of its motion. From this basis he proceeded to distinguish four distinct ‘Causes’ of things.

The rival Atomist school of thought claimed that a thing was completely explained when one knew what it was made of. Against this Aristotle argued that such information about its constitution specifies only its Substance, and so only provides us with what he termed its ‘Material Cause’ e.g. the wood of which my shed is made. In order to understand a thing completely we need to know three further Causes. A ‘Formal Cause’ must be identified. This specifies the Form or design it possesses. Next, we seek its ‘Efficient Cause’: to determine the agent which directly produces the object by embodying the Form in some material substance, i.e. the builder of my shed.

This ‘Efficient Cause’ is closest to what modern scientists would call a ‘cause’. Finally, there existed what Aristotle considered was the most important cause, the ‘Final Cause’ the purpose for which the object exists. From the idea of Final Causes there arose a teleological view that events evolved necessarily towards some goal or purpose, as if they were magnetically attracted by it. This idea was to create a world-view that dominated the West for more than a thousand years.

Broadly speaking, the Greeks viewed the Universe as a living organism rather than as a mechanism like a watch. This had much to do with Aristotle’s identification of Final Causes, for living beings indulge in purposeful behaviour. If one believes the World to work by analogy like a living organism then one will arrive at a belief in natural events having purpose.

Regularities in the mechanical and inorganic world do possess the clear feature that past causes determine future effects: we kick a stone, and then it moves. But in the realm of living things the relationship is superficially quite the opposite.

The future seems to determine the present; we do things with some future purpose in view, such as squirrels gathering nuts in order to prepare for their winter seclusion. This teleological aspect of the natural world, and Aristotle’s particular interest in animal behaviour led to the incorporation of Final Causes into his fourfold scheme of causes in a leading way.

What you conclude from this view of the world will depend upon what you come to think about the ‘end’ to which events are being purposefully directed. Aristotle characterised this ‘end’, not just by what happens last, but as a perfect state possessing unique harmony. It is such a state that things naturally try to attain, and all motion takes place in accord with this tendency. This view was to prove a major stumbling block for scientific progress.

The idea that the Universe should be viewed as a living organism rather than as a machine (as it tends to be in modern times) is a strange one, but hardly an unexpected one amongst thinkers preoccupied with studying living organisms for the first time within a culture that had no experience of technology and machines. It illustrates to us what has always been the major source of erroneous scientific reasoning: not so much incorrect data or wrong theories, but the mistaken belief that an entire body of ideas that apply successfully to one phenomenon can be taken over and used to describe another quite different one - the false analogy.

The introduction of Final Causes set an authoritative seal of approval on a way of thinking that had existed sporadically before Aristotle, but which was to dominate later Western thinking. If Nature does work towards some purpose, then what better purpose than the good of Mankind? From these beginnings there developed the tradition of 'Design Arguments': explanations that things were as they were because they were constructed by the Deity either for the benefit of Man or to attain the most perfect harmony. The 'Laws of Nature' existed to make the Universe a fit place for Man to live in.

They had their particular forms because they were goal-orientated. Subsequently, those who sought to use Aristotle's philosophical scheme for theological purposes usually added an additional 'First Cause' to the four Aristotelian 'Causes'.

This would be the Creator or 'less grandiosely" the initiator of the garden shed in our earlier example.

One can see how appealing the symmetry of First and Final Causes might be to a theology that speaks of God as Alpha and Omega. The mystical ideas of Teilhard de Chardin, which aroused a surprising amount of interest in recent times, described a teleological cosmological view in which evolution proceeded towards a Final Cause which he termed the Omega Point.

The introduction of the idea of Final Causes was disastrous for the immediate development of science in the modern sense. A healthier outcome in the short term would have required attention to be focused upon trends and regularities in the character of Efficient Causes. Although the early Atomists did confine their interest solely to Efficient Causes, their views were not influential until they were revived long afterwards.

The future synthesis of Aristotle's philosophy with the Roman Catholic tradition was to stress the barren aspect of Final Causation as being a sufficient explanation for what was seen.

This doctrine became a celebrated argument for the existence of God, and grew extremely anthropocentric in its emphasis, regarding the well-being of Man as the goal of all natural phenomena, and basically the law of Nature.

Yet Aristotle was not so naive in his original formulation of the idea. He was neither anthropocentric nor animistic in his idea of Final Causes. Although a stone tends to fall towards the Earth, it does not desire to do this. A Final Cause had been introduced because Aristotle believed that if only the other three causes were invoked to describe motions, then this left natural processes crucially undetermined; anything could still happen. This ambiguity can now be avoided by linking every Efficient Cause with some Final Cause. In his astronomical studies of celestial motions the Final Cause of the motion really amounted to what we would now call a 'Law of Nature', in the sense that if the state of motion at one particular time is known, together with the Final Cause, then this determines how it will move in the future.

The actual future motion is completely specified. At first, it appears that Efficient Causes have become laws of motion while Final Causes act as boundary conditions to make the motion unique (although final rather than the now conventional initial boundary conditions), but it is the Final Causes that have in modern times become our 'Laws of Nature', while Efficient Causes have turned into the natural forces which those laws describe.

With the benefit of hindsight it is also clear to us that, although Aristotle's system of various causes does clarify different abstract aspects of things in general, it is somewhat obscure when we focus upon things in particular. There is no end to the list of indirect 'causes' that we could associate with the building of my shed. The lumberjacks who hewed the trees, the natural environment that allowed the trees to grow, the person who first conceived the idea of a wooden shelter - the list is endless. There are too many possible causes if one is interested in 'why' things happen rather than simply 'how'. It was by a considerable restriction of objectives that the scientific method eventually became both fruitful and unambiguous.

Chapter Six
Laws and Lawgivers

> *"Lo in the creation of the heavens and the earth, and the alternation of night and day, and the ships which run upon the sea with that which is of use to men, and the water which Allah sendeth down to men from the sky, thereby reviving the earth after its death, and dispersing all kinds of beasts therein, and (in) ordinance of the winds, and the clouds obedient between heaven and earth: are signs for people who reflect".* **Holy Qur'an 2:164**

The explicit metaphor 'Law of Nature' took a long time to emerge in scientific work. It was not an expression used regularly by the Greeks, and first appeared in its modern guise in the optical studies of Roger Bacon (1210-92) when he spoke of laws of reflection and refraction, and of things 'not following the 'Laws of Nature'. He also used the term 'law' (lex) to describe regularities in Nature in much the same way that we do. But he did not take this idea from the religious notion of a single **Divine Lawgiver**, as one might have expected. Rather, he saw many different rules for particular classes of phenomena. He did not advocate the more general idea of a single set of unifying 'Laws of Nature' with one source.

Thus he used the terms lex and regula when speaking of Nature. Whereas lex described legislation laid down by authority, regula (rule) was a guideline or a standard to judge things against, and this meaning has given rise to our present day expression 'as a rule', meaning 'usually'. Eventually the two terms would diverge in meaning, with lex coming to signify something inherent in things causing them to behave in particular ways, while regula became regularity, the property of events or sequences of instances of natural phenomena. For Bacon, his laws of light signified regularities of Nature, and not Divine decrees.

The more theological view that 'Laws of Nature' were Divine stipulations[11] arises more prominently among astronomers, who are not manipulating Nature to extract information but gazing at the heavens. Tycho Brahe (1546-1601) even claimed that ,

> *"The wondrous and perpetual laws of the celestial motions, so diverse and yet so harmonious, prove the existence of God".*

The Holy Qur'an, the religious text of the Muslims, also invokes the idea of a Divine Lawgiver in many of its verses, explicitly directing mankind to search out these laws from which Man could ascertain the existence of the Lawgiver.

The relationship between the Qur'an and science is surprisingly harmonious. In the west scientists are quite willing to mention Christianity or Judaism, when science and religion are discussed, but rarely do they think of Islam. Or when it is mentioned it is generalised.

The Qur'an does not aim to explain certain laws governing the universe, instead it gently guides the reader to ponder over these laws, to observe the universe in a deep and meticulous way so as to arrive at these laws. The Qur'an incites Man to reflect on the miracles of creation at every level, from the planetary motions, to the development of a baby in the womb, pollination of flowers and the formation of mountains and Continents.

> *"Behold! In the creation of the heavens and the earth, and the alternation of the night and day, these are indeed signs for men of understanding".* **Qur'an 3:190**

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11 It is interesting to recall the medieval view, well represented by Aquinas, which viewed the innate Aristotelian tendencies as aspects of the natural world which were providentially employed by God. However, in this co-operative enterprise their basic character was inviolate. According to this view, God's relationship with Nature is that of a partner rather than that of a sovereign as it becomes in the mechanical view when laws of Nature are imposed upon Nature from outside. The latter view took prior claim over the former following the condemnations of certain Aristotelian views by the Bishop of Paris, Ptienne Tempier, in 1277. The condemnations focused upon those Aristotelian conceptions which appeared to limit the free choice of God in the ordering of the Universe - for example the creation of a void. This opened the door to the mechanistic doctrine of freely imposed laws of Nature. Much later, this view was found conducive to the Reformation theologians, like Luther and Calvin, who laid great stress upon the sovereignty of God and the inflexible predestination of events ordained by God. The Reformers believed that no innate tendency of matter could determine the motion of things: only God could dictate such behaviour; and the laws of Nature were the expression of that dictatorial control.

“Will they not regard the camel, how is it created! And the heavens how it is raised! And the mountains how they are set-up! And the earth how it is spread”! **Qur’an 88:17-20**

A similar merger of the evidences of regularity in Nature with the biblical notion of a celestial ‘Law - Giver’ underwriting the uniformity of Nature was adopted by Descartes and Kepler. But gradually these investigators found that they had little need of a view of the origin of the regularities in Nature Given that they believed such regularities to be present, they made progress by observing and coding their observations in mathematical summaries without requiring a philosophy of science. After glimpsing the regularity behind the world, Kepler and Copernicus were motivated primarily by the desire to uncover more of it, not to interpret it or use it to support an extra-scientific philosophy. The meaning and the method of science were beginning to go their separate ways.

Kepler (1571-1630 C.E) was one of the first scientists to exploit a faith in the underlying simplicity and harmony of Nature to guide his thinking towards ‘Laws of Nature’. An ardent realist, he believed that God had fashioned the Universe using certain archetypes which were also present in the mind of Man because he was made in God’s image. This meant that it was possible for him to understand Nature.

The idea that the ‘Laws of Nature’ which were uncovered by Kepler and others, were merely temporary descriptions which contained no ultimate truth or value, was unacceptable to Kepler. He argued that there could not exist different, but equivalent, representations of the ‘Laws of Nature’ at the same time in this sense. If they were pursued far enough, and compared with enough observations, all except one would be revealed to differ with observation on at least one crucial point. Thus only one of the so - called equivalent representations was the correct one.

Kepler was also responsible for expressing the ‘Laws of Nature’ as mathematical equations. So successful were these expressions that this subsequently became the *modus operandi* of science: the true ‘Laws of Nature’ were now invariably mathematical laws. The medieval view had begun by regarding physical events as symbolic, but it ended when events were replaced by mathematical symbols. Such symbols were universal. They allowed science to grow in different places and be able to communicate its findings unambiguously. Things were no longer ‘explained’ if their teleological purpose could be uncovered: they were consistent, if they could be reduced to a single set of mathematical patterns. In time this would become the implicit definition of scientific explanation.

Kepler’s formulation of mathematical laws, founded upon observational data, were not wholly satisfactory. His first law of planetary motion stated that planets move in elliptical orbits. But a law of this sort does not allow one to predict where a planet will be at some future time on the basis of the knowledge of its current position. Such a development required the ‘wedding’ of Kepler’s astronomical picture with a more powerful mathematical technique.

The first steps in this direction were taken at Pizza by Kepler’s brilliant correspondent Galileo Galilei (1564-1642 C.E). Galileo was not content to deduce the ‘Laws of Nature’ from observation, but set about manipulating Nature in order to make the ‘Laws of Nature’ transparently evident. In order to capture nuances of the fall of bodies under gravity, he rolled them down inclined planes so that the effects were slowed down and amenable to study.

He was able to frame and test conjectures with great skill, and gradually built up a successful mathematical description of motions by a systematic experimental interrogation of Nature. He showed that Aristotle’s laws of motion did not agree with observation. Aristotle could have discovered this, but what Galileo was able to do, which Aristotle could never conceived to have done, was to believe in ‘thought experiments’ in which bodies fell with no resistance (in a vacuum!).

By this idealisation of a vacuum he isolated the essential features of the phenomenon of motion from the inessential. This habit of framing imaginary mental experiments shows the extent to which the new scientific method dictated the way in which scientific questions could now be decided. The result of these steps was, for the first time, a unified physics which was applied to all natural phenomena. It was the first science to ‘look’ and feel, modern. Its underlying methodology was quite different from that of previous natural philosophy. Herbert Dingle judged that its signature....

> *“... is that self-control, the voluntary restriction to the task of extending knowledge outwards from the observed to the unobserved instead of imposing imagined universal principles inwards on the world of observation. That is the essential hallmark of the man of science, distinguishing him most fundamentally from the scientific philosopher”.*

And, having achieved this and so much else, Galileo did something else distinctly modern: he set about writing ‘popular’ accounts of his discoveries for the general public.

Chapter Seven

Newton’s Mechanical Universe

“Very few people read Newton, because it is necessary to be learned to understand him. But everybody talks about him”. **Voltaire**

The most fascinating development in the advancement of our notion of the ‘Laws of Nature’ came with the work of Isaac Newton (1642-1727). His contribution to what is known about Nature was the greatest that has ever been made by a single individual, but it is not for this reason alone that he is of interest to our story. Unlike other great scientists living shortly before him, Newton’s work had a dramatic influence upon an entire culture. His genius was not met with the censure and persecution that greeted the outspoken and tempestuous Galileo; it was troubled only by constant personal arguments over priority, first with Hooke and then with Leibniz. It created a whole philosophy of Nature, and started the popularisation of science for the general public in the English language. Surrounded by the favour of Church, Queen, and Government, Newton’s pre-eminence became the centre around which the Royal Society re-established its fading scientific prominence and intellectual respectability.

Newton arrived at a propitious time. The Copernicans had set science upon a course that no longer saw Man as the focus of things. Galileo had developed the mathematical method to the extent that there now existed well-posed problems. Communications and nascent scientific societies fostered the exchange of ideas and information. The social respectability of science attracted the patronage of wealthy and influential figures. The rise of active experiment, rather than passive observation, had attracted craftsmen of great skill to the scientific enterprise. Instruments were designed and built for the sole purpose of observing the world in wider and finer detail. What the microscope and the telescope revealed fired curiosity beyond measure.

Whereas Leonardo da Vinci a practical genius of the Renaissance displayed a vast diversity of interests, and catalogued and drew examples of everything he saw, Newton saw many things with a deep unifying understanding. He invariably recognised the essential common factor behind superficially different phenomena, and as a result there was henceforth to be a strong emphasis on the mathematical regularities of Nature rather than its eccentricities. This single-mindedness enabled Newton to isolate a collection of profound ‘Laws of Nature’ that survive today as an excellent approximation to the behaviour of bodies moving at speeds much less than that of light. So successful was the Newtonian theory of the world that realism appeared with a new force. It was widely believed that Newton had found the ultimate laws of the Creator.

Newton saw clearly that the Aristotelian heritage which had been bolstered by the nit-picking of the Scholastics was sterile. It was an argument about the innate properties of things which sought the reasons for these properties in the peculiar intrinsic strivings of the things themselves. Newton was interested in finding general rules which determined how things happened;[12] he was not interested in the insoluble problem of why they happened, because he believed that it was possible to say ‘how’ without any reference to the issue of ‘why’. In the introduction to his Principia he writes that in the past philosophers were employed in giving names to things, and not into searching them out. He goes on to establish a scientific method that is intended to rectify this imbalance. Of this method he claims:

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[12] Here, there is a contrast with the traditional Aristotelian view that matter was steered by innate tendencies rather than by externally imposed laws. In 1693 Newton wrote explicitly of this to Richard Bentley 'That Gravity should be innate, inherent and essential to matter ... is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking, can ever fall into it.' Newton saw these external laws as imposed directly and completely by God just as society imposed laws upon its citizens. This gave rise to conflict with Leibniz who reiterated the Aristotelian view that matter possessed innate tendencies and led to Samuel Clarke's claim in correspondence with Leibniz that in the Newtonian picture there are 'no powers of nature independent of God'. We are so familiar with the concept of imposed laws (whether or not we appeal to God as the legislator) that it is easy to overlook the type of mental block there might have been to this idea. At a time when vitalist notions separated the living from the non-living world and the mind of man set him above everything in Nature, one would have to accept that God's laws could be 'understood' and responded to by inanimate objects by analogy with the human response to moral and social laws.

"These Principles I consider not as occult Qualities, supposed to result from the specific Forms of Things, but as general 'Laws of Nature', by which the Things themselves are formed."

Newton's method was not totally revolutionary, and we can be confident that he spelt out its basic axioms long after he had evolved it by intuitive use in solving problems. Nor is it enough to possess a correct philosophy of science in order to make scientific discoveries.

As a prelude to considering Newton's laws of motion let us take a look at some of those devised by Rene Descartes (1 596-1650 C.E), who died a few years after Newton's birth. Descartes referred to these laws as 'Rules of Nature' in 1644, but after 1647 adopted the terminology 'Laws of Nature'. They 'look' mathematical. They are derived from observation. They deny any system of final causes. Nonetheless, they are incorrect. However good the scientific method of the scientist, it is still necessary for the world to be observed correctly.

The terminology 'laws of motion' seems to have become common following the papers of Descartes, Huygens, Wallis, and Wren on the behaviour of colliding objects. The law suggested by Descartes is interesting as an example of an incorrect law of motion that was to be superseded by Newton's. Descartes' law of motion has two parts, and predicts the results of a collision between two masses:

1. If two bodies have equal mass and velocity before they collide then both will be reflected by the collision, and will retain the same speeds they possessed beforehand.
2. If two bodies have unequal masses, then upon collision the lighter body will be reflected and its new velocity become equal to that of the heavier one. The velocity of the heavier body remains unchanged.

Descartes had derived both these laws on the basis of apparent symmetries and a notion that something must be conserved in the collision process. Unfortunately, Descartes' proposals possess the same defect that marred Aristotle's proposals: the problem of discontinuity. This was first pointed out by Leibniz.

Newton observed the world both more carefully and more widely than did Descartes, and also had the advantage of Descartes' own wide insights before him. The laws of motion that Newton laid down were published in 1687, although they were worked out long before that. Unlike the present-day scientist, Newton was in no hurry to publish or otherwise announce his discoveries. Indeed, it may only be a consequence of prodding by his friends that much of his work became known at all. One certainly suspects that, faced with the prospect of the public and official opposition ranged against a Copernicus or a Galileo, Newton, 'with his prism and his silent face', might have taken many of his discoveries to the grave in secret. Fortunately he did not. Newton's three momentous laws of motion were stated by him as follows:

1. Every body continues in its state of rest, or uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.
2. The change of motion is proportional to the motive force impressed; and is made in the direction of the straight line in which that force is impressed.
3. To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal, and opposite l3, directed.

The most interesting of these statements is the first law. We normally encounter it at school in more familiar language (Newton wrote originally in Latin), as the statement that 'bodies acted upon by no forces remain at rest or move with constant velocity'. In an earlier draft Newton expressed it first as:

> If a quantity once move [is moved] it will never rest unless hindered by some external cause,

and then as:

> By its innate force alone a body will always proceed uniformly in a straight line provided nothing hinders it,

before its penultimate rendering as:

> By reason of its innate force every body preserves in its state of rest or of moving uniformly in a straight line unless in so far as it is obliged to change its state by forces impressed upon it.

In fact, this law owed much to Descartes, who was the first to discard the ancient notion that motion was some type of process and recognise the sense in which the states of rest and steady motion were similar. In 1644 his famous Principia Philosophiae contained the predecessor of Newton's first law:

> If [a body] is at rest we do not believe it is ever set in motion, unless it is impelled thereto by some [external] cause. Nor that there is any more reason if it is moved, why we should think that it would ever of its own accord, and unimpeded by anything else, interrupt this motion.

Newton's deductions differed from Descartes' in the way he had arrived at them by a variety of experiments and observations. In their support he cites observations of projectiles, tops, and planets. They also went farther because Newton recognised that whenever motion became non-uniform a force was acting. He also brings in the element of universality by his telling opening phrase, 'Every body'. We should not miss the intended contrast with Descartes' Principia Philosophiae when Newton calls his great work Philosophiae naturalis principia mathematica.

Newton's first law states that when there are no impressed forces there will be no accelerations. If you see a body moving with a changing speed or along a path that is not a straight line, then a net force is acting upon it. If you recall how different Aristotle's law of motion was; Aristotle claimed that force led to unaccelerated motion on Earth, and he also maintained (but only for philosophical reasons) that the natural celestial motion was circular. Circular, rather than straight-line motion was the natural state of the Aristotelian celestial world. Rest was the natural state of motion of objects in the terrestrial world. Newton would have told Aristotle that force was the 'efficient cause' of acceleration.

What is so interesting about Newton's remarkable statement is that neither Descartes, nor Newton, nor anyone else had ever seen a body that is acted upon by no forces. Everything feels the force of gravitational attraction exerted by the other bodies in the Universe, and in any particular situation a body will usually feel all sorts of other inevitable forces as well. There is no known way of insulating bodies from all forces.

We cannot just turn off the forces of Nature. Indeed, some of these forces hold solid bodies together. This means that Newton did something far more sophisticated than his predecessors; he did not simply write down an empirical description of what is seen in Nature, because his first law describes a situation that had never been seen, nor ever will be.

It is not a straightforward realist's discovery of what the world is like, because there are no objects in the world meeting the stipulations of the law; although Newton did believe he was describing an underlying reality, not just 'saving the appearances'. It is not an operational statement either: it does not tell us how we should measure forces or velocities. It seems closest to the spirit of the Platonic idealist. Newton envisaged an ideal situation which was conceived by his observation of large numbers of non-ideal situations.

Modern physicists would call this a 'model'. He approximated circumstances to those where there are opposing forces acting upon a body but they almost cancel each other out, and leave no net force acting upon the body, to a very high degree of approximation. His first law is a creation of the mind in that spectacular sense. It is an abstraction that captures the essential elements of the real. It involves an intuition as to what the various forces acting all are, and to endow them with equal status.

Later scientists were to follow this course on many occasions. The art of formulating good 'Laws of Nature' incorporates the ability to recognise which aspects of a situation were inessential. No statement of a 'Law of Nature' is able to take into account all the observational factors involved in a particular natural phenomenon.

It is too complicated. Rather, the mark of the potent scientist is to see through the inessentials and concentrate on the dominant feature. But the law that results must be such that it would remain true if all the inessential neglected secondary features of the world were incorporated into our description. One is not ignoring these features because they are awkward counter-examples, but because they introduce no new points of principle. If their inclusion were to render the derived law false, then they would no longer be inessential.

As Newtonian physics grew, there appeared the notions of frictionless surfaces, ideal gases, perfect conductors of electricity, inelastic collisions, perfect insulators, perfect spheres, and so on.

None of these entities exist in the real world, but a law is most usefully formulated in terms of what the behaviour of such 'ideal' objects would be if it was the limiting case of a continuous sequence of situations approximating more and more closely to that of the ideal one. Thus, we make use of the principle of continuity employed so tellingly against Descartes' law of motion, to arrive at the more general aspects of physical laws. The ideal object is regarded as the limit of a sequence of observable ones, rather than as an other-worldly blue-print. This approach maintains a divorce of physics and philosophy created by Descartes.

Newton was never involved in debates about Platonic idealism. Laws of this kind allow one to assess the behaviour of real things by the extent of their deviation from the ideal behaviour.

As the situation we wish to describe approximates more and more closely to the ideal one postulated by our law, we expect the behaviour of the real situation to approach increasingly closer to the behaviour stated in the law.

In practice it is not possible for our measurements and observations to be perfectly accurate and so there is no way in which we can ever confirm whether a law is almost, rather than precisely true.

Newton was interested primarily in how things happened in Nature, not in philosophical arguments. Why they happened or for what ultimate purpose they were intended was not his concern. Nevertheless, he did not regard these latter issues as meaningless or irrelevant; indeed, he spent the greater part of his time pursuing unusual metaphysical and theological interests[13] . Newton regarded these matters as questions whose answers could not be obtained by the careful observation and experimental interrogation of Nature. Judging by his alchemy and religious writings, which considerably outnumber those concerned with scientific matters, he clearly believed that some of these questions were able to be answered by other methods.

Newton considerably narrowed the objectives of natural philosophers, but he did so to great advantage, for he was able for the first time to confine their attention to the realm of soluble problems. By narrowing his objectives, he was able to make the remarkable claim that the uncertain speculations so beloved of his predecessors 'hypotheses' as he termed them, were unnecessary to his enterprise. There was a fool proof way of deriving the 'Laws of Nature', or scientific theories, from experience alone: experimental investigation. This scientific method is the one we still employ today. It seems so obvious a way to proceed that it is hard for us to see how anyone could ever have thought differently - but we did.

The Aristotelian tradition had encouraged observation but not experiment. When Galileo's opponents were confronted with the evidence of observations made with his telescope, they maintained at first that they were unreliable because of the distortion of reality created by lenses and other observing instruments. The idea of manipulating events to extract information about the world, was a foreign idea to the ancients.

This idea developed in Europe through the influence of craftsmen and engineers as much as through that of natural philosophers. Newton's methods allowed him to investigate the behaviour of phenomena by carrying out controlled experiments in order to test his ideas systematically. Many of Newton's contemporaries were still sceptical of determining the nature of things from the data of practical experience rather than from some all-embracing philosophical principle.

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[13] It is amusing to consider why one never finds Newton ridiculed for calculating and publishing a date of 3988 BCE for the creation of the world, in the light of the derision that Bishop James Ussher (a contemporary of Newton's) still seems to attract with a date of 4004 BC!

Their doubts were not entirely without foundation. They believed, as classical ideas about the purpose of things would tend to encourage one to believe, that there was no unique interpretation of the observations one made. This encouraged a manifold of speculation with no motivation to determine a unique and correct explanation. In fact, Newton was not opposed to interpretations or speculations as such, but only to those who would use such hypotheses as an excuse for not carrying out real experimentation when it was possible. His distaste for 'hypotheses' is the natural reaction of a man in possession of a far superior instrument for discerning the truth from error.

From then on, general philosophical statements could no longer assume the status of the 'Laws of Nature'. Only those statements that had passed the test of experimental check against the manifest facts of experience, would receive this accolade. Newton completed the divide between the meaning and the method of science.

The distinction between Newtonian science and 'hypotheses' was clearly delineated by Newton's second great innovation: the use of mathematics. This was the method by which new possibilities would now be generated for testing by experiment. Newtonian physics was mathematical physics. In all his investigations, Newton sought to express the 'Laws of Nature' in mathematical terms, so that they would be completely unambiguous.

When the necessary mathematics could not be found, he formulated it himself. In this way, some of the most important mathematical tools ever invented were introduced into the physicists' armoury. The most powerful tool was calculus, by which continuous changes could be described through mathematics. Given the starting configuration, the future could be predicted or the past reconstructed. This step completed a gradual change of emphasis in the scientists' way of thinking about the ultimate 'nature' of the world they were studying.

Amongst Newton's many achievements, there is one which, in retrospect, stands out as being the greatest discovery for the future course of thinking about the 'Laws of Nature' this is the 'Law of Gravitation'.

In this discovery, Newton made good use of important earlier discoveries about the celestial motions made by Kepler and others. Newton was aware of a law of this type in the mid 1660s. During this creative period, he wrote nearly half a century later that,

> *"I deduced that the forces which keep the planets in their Orbits must [be] reciprocally [the same] as the squares of their distances from the centres about which they revolve".*

However, the first written version of Newton's law of gravitation that has been found, is that contained in an unpublished and untitled manuscript now given the title of *On Circular Motion*, probably written in 1665 C.E. It was this manuscript that Newton cited in his correspondence with Halley as evidence of his priority over Hooke, with respect to the discovery of the inverse-square law. There, the 23 year-old Newton deduced the 'Inverse-Square Law' from Kepler's third 'law' of planetary motion. Newton also used the definition of the centripetal force required to sustain circular motion, and concluded that,

> *"Since in the primary planets the cubes of their distances from the Sun are reciprocally as the squares of the number of revolutions in a given time (Kepler's third law): the endeavours of receding from the Sun will be reciprocally as the squares of distances from the Sun".*

By introducing this constant element in a mathematical formula, Newton took a dramatic step forward. He claimed that all bodies, be they celestial or terrestrial, were subject to this self same 'Law of Nature'. They all felt the same intrinsic strength of the gravitational force, no matter what their separations or masses.

By his unification of all the effects of gravity, Newton was responsible for identifying '**G**' as the first 'Constant of Nature' in any 'Law of Nature'. This constant is still credible today. Even though Newton's theory of gravitational forces was subsumed within Einstein's theory of general relativity in 1915, this new theory still retains Newton's 'constant' **G** in a similar capacity.

What do we mean when we say that a quantity is a 'Constant of Nature'? It means that it is independent of the identity of the bodies whose masses are **M** and **m**, independent of all their physical properties and all other physical conditions - the time and place of measurement, the temperature of the laboratory, and so on. The identification of such quantities aimed to set science upon a fruitful course. this has now culminated into a perspective in which a large part of our picture of the structure of the Universe, is contained in the numerical values of a small number of fundamental 'Constants of Nature' which still includes Newton's **G**. It is the set of particular values which these quantities are observed to take, that gives our Universe its particular physical qualities. As yet, we do not know why these constants of Nature possess the particular numerical values that they do.

Newton's introduction of a universal constant of gravitation highlights another important point. The proportional dependence upon the masses and the separations is a relationship that can be determined by theoretical reasoning from more elementary principles, but the value of the constant of proportionality can be obtained only by observation. This division of the 'Laws of Nature' into functional dependencies between quantities (here it is between force, mass, and distance) and universal proportionality constants, is a continuing feature of science to which we shall return.

Suffice it to say that the goal of physicists is to reduce the number of 'Constants of Nature' to an absolute minimum, whose values need to be ultimately determined through systematic observation of their theories. This economy drive is pursued by trying to show that what we previously thought to be independent 'Constants of Nature', are in fact related either to each other, or to more basic variable quantities. To the ancients, the world was a living organism, but to Newton and his followers it was a unified mechanism - like the interior of a giant clock. Its workings were pristine, precise, mechanical, and mathematical. Once set in motion by the **Creator,** they continued by their own inexorable internal logic.

Where the God of the Scholastics was Omega, the ultimate Final Cause; the God of Newton was Alpha, the pre-existent First Cause of all things. This strong belief in the deterministic character of the world owed much to the religious thinking of that era. The prevalent Christian view of the one God who laid down the 'Laws of Nature' and upheld them by the word of His power, led to a strong faith in the rationality, consistency, and predictability of Nature. However, it should be recognised that these laws had been pursued and discovered at least in part, because of a belief that a 'Law - Giving' Deity existed. Part of Newton's long-standing quarrel with Leibniz was associated with these ideas, which Leibniz thought blasphemous because they gave the Deity no scope to intervene in Nature after the initial act of Creation.

Newton's first universal description of a natural phenomenon was heralded by the supporters of his methods as the uncovering of a fundamental law of Nature.

It was the uncovering of such a universal property that gave support to religious apologists like William Whiston, who argued that it bore witness to the **unity** of **Creation**, and thereby to a unique Creator. It was too remarkable to be viewed in any spirit other than the realist's and it became the mainspring of the new mechanical paradigm of a clockwork Universe, running to definite mathematical rules.

It saw the foundation of an approach to science that has subsequently characterised 'English-speaking' scientists ever since - the emphasis placed on reducing everything to a visualised mechanical picture. The continental approach has traditionally been more abstract, not requiring a mental mechanical model of a complicated phenomenon before claiming it to be understood. An abstract mathematical description sufficed. The British passion for visualisable models was a psychological feature that especially exasperated Henri Poincaré at the beginning of the 20th century. As a distinguished representative of the French appetite for abstract thinking, he claimed that there was no need to reduce everything to the mechanical analogies so beloved by the empirical British scientists.

This love of mechanical analogies as a device for explaining complicated abstract physical concepts, is a virtue and a vice, that still dominates the popularisation of science in the English language. It is, in many ways, an inheritance of the Newtonian style: the deduction of great truths about the workings of the Universe using simple mechanical experiments, and the belief in the paradigm that Nature really is a great mechanism - and perhaps the suspicion that God, like Newton, is an Englishman!

Newton's approach to the investigation of Nature brought about the greatest single advancement in human knowledge of the Universe's workings, that has ever been effected by one man. But the publication of the monumental *Philosophiae naturalis principia mathematica* in 1687 and *Opticks* (in English) in 1704, led to more than a revolution in scientific thinking. It changed the thinking of non - scientists as well.

The *Principia* became the first scientific 'cult' book (that is, a book that is read about, but not read), and it created what we might call 'Newtonianism'. This had many consequences, the most interesting of which was the start of the systematic popularisation of science through the publication of elementary explanations designed for the lay-person. A vast number of such books were written in the first half of the 18th century to satisfy public interest in Newton and his discoveries. At the opening years of that century, Newton had established a public reputation unequalled by any British scientist before.

Whereas the intellectuals of the past had arrived at grand conclusions concerning the nature of the Universe by complex and subtle verbal reasoning, Newton's insights were particularly extraordinary in that he employed simple, mundane objects. For example, the laws of optics were derived from a simple prism, the laws of motion were discovered by dropping things to the ground (even apples, perhaps).

The general public did not understand these discoveries (which only served to heighten their fascination; a similar effect occurred with Einstein, unlike the case of Darwin where the public could understand only too well what he had discovered), but the lay-person wanted to know what this new thing called 'Newtonianism' was.

We have already discussed how Aristotle's ideas about final causes led to the development of an anthropocentric teleological interpretation of Nature, which Man interpreted all good things around him as providentially made for him rather than simply things happening by chance around him of which he could subsequently make use of. Newton's work gave a new impetus to the traditional Design Argument that the workings of Nature were so wonderfully contrived for our advantage that they must be the result of an all - embracing Divine plan. Whereas the earlier and cruder Design Arguments had argued that natural phenomena were optimal for Mankind's use, and therefore demonstrative of Divine purpose, the Newtonian Design argument appealed to the universal 'Laws of Nature' themselves as incontrovertible evidence that bore witness to the plan of 'Nature', and hence to the **'Planner'** behind it.

The realist view was that the Newtonian system of laws described the world as it truly is - a view that Newton himself would not have defended, on account of his provisional attitude towards action at a distance - which did not just provide a useful description, was a natural complement to a belief that the 'Laws of Nature' were the edicts of a Divine Lawgiver.

The argument was enthusiastically inverted: the Newtonian watch-world required a watchmaker. The earlier Design Arguments were, of course, strongly associated with the Scholastic tradition of 'final causes' which had become anathema to the post-Reformation Protestant orthodoxy of Newton's time. Newton, along with his friend Samuel Clarke, appears to have entertained Unitarian beliefs concerning the Holy Trinity and other fundamental Christian doctrines.

An Act of Parliament passed in 1689 debarred those holding such Arian[14] views from holding certain academic and public offices.

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[14]Arius was a fourth-century Libyan theologian who rejected the doctrine of the **Trinity**, the primary architect of which was Athanasius. Newton's private papers reveal that he questioned almost all the main doctrinal teachings of the Church and persistently maintained that the original Scriptures had been **corrupted by the addition of spurious passages during the fourth and fifth centuries**,

Newton was only able to remain as Lucasian Professor at Cambridge because a special dispensation was granted in 1675 which permitted the holder of this chair to remain a Fellow of his college without taking holy orders in the Anglican Church. Newton does not seem to have held his minority religious opinions by default. He researched the subject passionately, tracing the historical basis of the creeds through the history of the early church, and was regarded as something of an authority upon these matters.

Newton's voluminous writings on biblical criticism show him to have been the first liberal textual critic. He attempted to lay down 'rules' for the interpretation of scripture which mirrored those that he had proposed in Principia for philosophical reasoning. However, some of this work was regarded as completely bogus even by his otherwise admiring contemporaries, and was not fully investigated by scholars until the 20th century.

With regard to Newton's religious views, a telling fact is Conduitt's record that Newton refused the sacrament of the church on his deathbed. Indeed, so shocking was this fact that the witnesses kept it a secret for fifty years after his death, and none of his early biographers recorded it. By contrast, William Stukeley records a deathbed scene which may have been partially invented by Conduitt and his wife, because it speaks of Newton's final moments as 'truly Christian'. Newton himself did not actively promulgate the Design Argument from the 'Laws of Nature' but he does remark, in the preamble to his Principia, that when composing it 'he had an eye upon arguments' for belief in a Deity, and that he encouraged the use of his work by others who wished to support a Newtonian Design Argument.

His famous correspondence with Bentley, which contains so many remarkable scientific insights, arose as a result of Bentley being chosen to deliver the first Boyle lectures. This lectureship was endowed in the will of Robert Boyle with the express purpose of providing scientific Christian apologetics. Bentley's three sermons provide a classic statement of the Newtonian Design Argument based upon the existence of the mathematical and universal 'Laws of Nature', and were prepared with Newton acting as his scientific 'conscience'.

The practice of producing examples of the meticulous contrivance of the 'Laws of Nature' for human benefit, and the existence of environments tailor-made for the flora and fauna that inhabited them, became a major industry which was only stopped dead in its tracks by Darwin's publication of the Origin of Species in the mid 19th century. This undermined the claim that the harmony between living creatures and their habitats, could only be explained by design, although it was quite irrelevant to the Newtonian Design Argument from the 'Laws of Nature'.

For examples of Newton's influence upon religious thinking and the influence of the 'Laws of Nature' upon 'design' in Nature, one has merely to refer to a church hymn-book. But this Newtonian interpretation of Nature was not without its critics. William Blake saw the mechanical world view as the inexorable and depressing machinery of 'dark satanic mills'.

Before leaving Newton we should draw attention to one last issue regarding the concept of the 'Laws of Nature' which was brought sharply into focus by the popularisers and followers of the Newtonian philosophy: the question of miracles.

In Newton's day, religious problems of this sort were a big issue, and so we find much discussion as to the compatibility of the Newtonian world, with its God-given 'Laws of Nature', with the possibility of miracles. Indeed, this was precisely why David Hume devoted so much space to undermining the credibility of miracles in his *Dialogues Concerning Natural Religion* (1779). Some took the view that there were two classes of phenomena: one 'natural', governed by the Newtonian 'Laws of Nature', and the other 'miraculous'.

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added solely to bolster an **invented doctrine** of the Trinity. Newton maintained that the former, uncorrupted version of Christianity issued from Arius, rather than Athanasius, and Newton's writings entitled *Notable Corruptions of Scripture* record theories about these corruptions of the early Church. Newton seems to have been the principal recreator of interest in the Arian heresy after it lay dormant for centuries, following its condemnation by the doctrinal Councils of the early Christian Church. This will be investigated further in subsequent books.

By observing what occurs, they claimed that one could then discern whether one was witnessing a miracle or not. Pieter Van Musschenbroek wrote that the miraculous phenomena ‘happen contrary to the ‘Laws of Nature’’.

Although he believed that our knowledge of Nature’s laws was incomplete, he did not argue that apparently miraculous phenomena would eventually be regarded as natural when new laws were discovered. Other authors took the view that the ‘Laws of Nature’ were simply descriptions of what did occur, and although they were witness to certain habitual trends, they forbade nothing. John Rowning sums up this view of his contemporaries in this manner:

> *“Doubtless the Author, both of matter and of those very principles by which it acts can, notwithstanding those principles, cause it to act differently from what it would do in consequence of them alone, and so by that means, produce effects contrary to the common Course of Nature, whenever he shall think proper ... Upon the whole therefore, to presume, that the ordinary and common Course of Nature is not sometimes altered, is hasty and unwarrantable”.*

In the immediate post-Newtonian era we find the term ‘Laws of Nature’ explicitly used in texts, conventionally defined in the grand Newtonian manner at the outset, and widely incorporated into religious apologetics. Nonetheless, an uneasy relationship persisted between the appeal to the universality of these laws as being the ‘Laws’ of God. There was the problem and risk that they might then be perceived as God. Newton foresaw these dilemmas, and we find in Cotes’s Preface to the second edition of the *Principia*, the following statement about the conflict between the necessity of certain ‘Laws of Nature’ and Divine choice:

> *“Without all doubt this world, so diversified with that variety of forms and motions we find in it, could arise from nothing but the perfectly free will of God directing and presiding over all. From this fountain it is that those laws, which we call ‘Laws of Nature’, have flowed, in which there appear many traces indeed of the most wise contrivance, but not the least shadow of necessity ... He who is presumptuous enough to think that he can find the true principles of physics and the laws of natural things by the force alone of his own mind, and the internal light of his reason, must either suppose the world exists by necessity, and by the same necessity follows the laws proposed; or if the order of Nature was established by the will of God, that himself, a miserable reptile, can tell what was the fittest to be done. All sound and true philosophy is founded on the appearance of things ... men may call them miracles or occult qualities, but names maliciously given ought to be a disadvantage to the things themselves, unless these men will say at last that all philosophy ought to be founded in atheism”.*

Chapter Eight

Reason and Belief

"The fact that we can describe the motions of the world using Newtonian mechanics tells us nothing about the world. The fact that we do, does tell us something about the world".
Ludwig Wittgenstein

By the end of the 18th century, the design arguments had become part of orthodox religious thinking in Britain, but cogent objections began to be raised which were also implicit criticisms of the rationality of the new scientific enterprise itself. There were two notable contributors to this sniping who are now regarded, rightly or wrongly, as two of the most important philosophers since the ancients - although in their own day their influence in Britain went essentially unnoticed.

David Hume and Immanuel Kant both took issue with the logical basis of the Design argument. In his 'famous' *Dialogues Concerning Natural Religion*, Hume associates it especially with Newton, even though it was a much older notion, and quotes the statement of it given by Maclaurin in his popularisation of Newton's work. Hume refers to it with a touch of irony as 'the religious hypothesis'. It is clear that the Newtonians held a straightforward realist view of the 'Laws of Nature' which they had found. The world was really a mechanism which obeyed the precise mathematical rules Newton had found (they did not ascribe any significance to Newton's idealisations). Hume did not accept that there was any unique interpretation of the lawfulness of the Universe - even if he were to be convinced that it was lawful.

This elegant idea turns out to be the equivalent to Newton's 'laws of motion' (although it is more powerful in the sense that it can be used to derive the equations of motion in other areas of physics once the appropriate action is identified). But unlike the formulation of Newton, it is teleological. It says that of all the paths that could be taken by a body moving from A to B, it actually takes that path for which the associated action is a minimum. This path is therefore determined by both the initial and the final states. Maupertuis attached great metaphysical significance to this result, regarding it as a 'proof' of the existence of Him who governs the world'. Formerly, arguments of this sort, that we lived in the 'best of all possible worlds' were open to the objection that we did not know any other worlds with which to draw such a comparison, but Maupertuis claimed that the other worlds were those in which motion occurred with non-minimal action.

Our world was optimal in this well-defined sense. Moreover there existed a teleological aspect to the 'Laws of Nature' (in fact, some 19th century commentators interpreted the existence of fossils as relics of the still-born worlds of non-minimal action). What is instructive about these eccentricities is that they exhibit how one image of the 'Laws of Nature', appealed very much to the English scientific mind.

The Design Argument would be overthrown, not by philosophical objections to its logical soundness, but by the idea of Darwinian evolution. Darwin was able to provide another explanation, itself rooted in detailed observations, for the mass of detailed observations supporting an apparent design in the make-up of the natural world. It was because Darwin provided an alternative explanation for the naturalists' observations that his theory was influential and received acclaim, not because he undermined the logic of the Design Argument. It was the alternative explanation which gave the Western philosophers the impetus to break the chains of authoritarian church dogma. This freedom from the yoke of the church gave the thinkers and philosophers of Europe the chance to finally break all ties to religion and develop the precursor to the modern day 'secular democratic state'. The influence of church and religion in general was confined to issues of morality and personal salvation and would no longer be allowed to play a role both in state or scientific inquiry[15].

[15] The subject of evolution and its impact on Western civilization, particularly the development of science and state is the subject of volume two of the prsent work.

The Newtonians lived in the post-Copernican era. Although Man was undoubtedly at the centre of their view of the world, he was no longer at the centre of their model of the world. To adopt Kant's approach, would have seemed like a step backwards into the pre-Copernican era in which Man was the focus of all things. This is because idealism assumes that the mind of Man should be the focal point in the understanding of our universe.

In the past as well as the present, scientists placed most of their trust in philosophical discourses written by scientists.

For this reason the most influential work on the philosophy of science written in the first half of the 19th century was John Herschel's Preliminary Discourse on the Study of Natural Philosophy. Herschel believed that the 'Laws of Nature' could be understood and learnt through observation. The scientist, he writes, is concerned with

> *"what are [the] primary qualities originally and unalterably impressed on matter, and ... the spirit of the 'laws of nature'.*

This statement of what amounts to naive realism, illustrates the limited impact of Kantian thinking upon the mainstream of British science of the period.

Subsequently, the most vociferous attack upon the uncritical subscription to a grandiose view of the 'Laws of Nature', came from the emerging positivist movement which denied any ontological authority to scientific law. It adopted a rigid operationalist stance. William Jevons and Karl Pearson were the most influential writers representing this view, and they attempted to downgrade the status of the 'Laws of Nature' by regarding them as approximations and an outgrowth of a purely mental activity. Jevons claimed 'that before a rigorous logical scrutiny, the reign of law will prove to be an unverified hypothesis, the Uniformity of Nature an ambiguous expression, the certainty of our scientific inferences to a great extent a delusion'. He regarded the 'Laws of Nature' as propositions, grounded only in probability about the correlation of events.

Furthermore, Jevons interpreted the Second Law of thermodynamics as an argument against assuming the constancy of Nature. The Second Law pointed to a beginning to the Universe, and to a most unusual future in which conditions would be totally unlike the present. Pearson was more radical. He regarded the 'Laws of Nature' as purely mental responses to sensations about the world. But it would be true to say that the dominant physical scientists of the day did not subscribe to these more subtle views of the 'Laws of Nature'. The Faradays, Maxwells, and Kelvins were deeply religious men who adopted, without question, the view that Nature's laws were real and that they were imposed upon her by Divine decree.

Until the mid-19th century, one had a clear choice regarding the structure of the world. Either it was a cosmos or a chaos. If one held the former view, then its order must have a definite source, whilst the latter option flew in the face of everything that we saw in Nature. The 'Laws of Nature' which laid bare the machinery of the world, bore witness to its inner workings, and persuaded both scientists and clergymen that the Author of those 'Laws of Nature' was the essence of its order and logic. But then a new doctrine began to emerge which has influenced attitudes towards the origin of order in Nature ever since.

In 1813 an expatriate American physician employed at St Thomas's Hospital in London, read an extraordinary paper to the Royal Society. The name of the physician was William Wells, the title of the paper: *An Account of a White Female, Part of Whose Skin resembles that of a Negro*. Wells's paper was published in 1818, in it, Wells proposed what we now call the process of 'natural selection' as an explanation for the existence of extant physical characteristics in living things. He derived the hypothesis from his case study of the adaptation of human skin coloration to climate. He argued, in contradiction to the prevailing view, that artful design was unnecessary in order to explain the remarkable adaptation of living things to their environments. If we could affect adaptation by the artificial selection imposed by breeding, then this adaptation could be achieved 'with equal efficiency, though more slowly, by nature'. Moreover, Wells appreciated that there was no such thing as the 'uniformity of Nature'; the natural world was in a state of perpetual change, and the process of adaptation could never be complete.

These views were both important and radical. One might have expected them to have sparked off all manner of opposition and public comment. Not so; they influenced nobody; they were cited by nobody; they attracted neither praise nor approbation. It is difficult to determine why this was so. Wells was a respected scientist, a Fellow of the Royal Society, and the winner of the Society's Rumford medal in 1814 for his classic analysis of dew-drops.

It is just possible that by publishing his paper on natural selection merely as an appendix to his Rumford prize-essay he actually ensured that it was overlooked, since the essay was widely cited by philosophers of science as a classic example of the scientific method at work. Whatever the reasons for Wells's original neglect, he appears eventually in the later editions of Darwin's Origin of Species, acknowledged as the originator of the idea of natural selection, after Darwin's attention was finally drawn to his work by an unknown American scientist in 1860.

Darwin and Alfred Wallace went much further than Wells in gathering evidence for the mechanism of natural selection. An explanation for the correspondence based solely on what is seen can give the complete opposite metaphysical impression to that obtained from another image which generates existence of order in the organic world. Through their work a new type of explanation became legitimate.

If all possible variants arise at random in a reproducing system, then those variations which most enable the system to reproduce will subsequently survive with greater probability than those which do not. Those reproductions that are best adapted to survive in the environment in which they find themselves will do so more readily that those that are ill-adapted. Hence, time and chance can produce the remarkable match between the living creature and its environment. By this means, the spontaneous evolution of order can be explained without recourse to final causes or explicit supernatural design. This evolution through the ‘survival of the fittest’ completely undermined the traditional argument from design in the biological realm, although it did not undermine those Design Arguments based upon the advantageous character of the ‘Laws of Nature’ themselves. If anything, it reinforced this latter version of the argument, because now the remarkable contrivances between living things and their habitats was seen to arise as a result of the action of the ‘Laws of Nature’ over aeons of time, rather than as a result of invariance’s imposed upon the world.

Attempts to widen the scope of natural selection to encompass the ‘Laws of Nature’ themselves were made by T. H. Huxley (1825-95 C.E) and others, whilst conservative physicists like Lord Kelvin (1824-1907 C.E) opposed evolution for religious reasons, and also argued that there was insufficient time for the process of natural selection to have evolved human life by the present day. Others, notably James Clerk Maxwell (1831-79), restricted their opposition to attempts to apply the concept of natural selection outside the biological realm by pointing to the invariance’s of the microscopic world. In particular, Maxwell placed great stress upon the discovery that atoms (which he called 'molecules') were identical, and their properties were not subject to the process of natural selection. He realised that a line could be drawn at some level in the hierarchy of Nature, below which natural selection was unable to supply an explanation for order. That line would need to be drawn above the scale of the atom.

Already in the opening chapter of this book the reader will have detected the influence of the doctrine of natural selection. When faced with the task of explaining the existence of some state of very low a priori probability one now looks to ascertain whether, regardless of starting conditions, this special state is always attained after a long period of time. Moreover, some states will be found to be necessary for the existence of living beings to observe them. Regardless of how improbable their occurrence a priori, we should not be surprised to find them existing today. A priori it might seem extremely improbable that, of all the places where a planet could be situated in this vast Universe, the Earth should be found in orbit around a star. However, such a proximity is no doubt necessary for the evolution of intelligent life forms. The Darwinian perspective has further challenging things to say about metaphysical ideas. Take, for example, the Kantian notion that our view of nature is irreducibly conditioned by human categories of thought.

The pre-Darwinian Kantian must subscribe to the coincidence that all humans possess, and always have possessed, identical categories of thought. A Darwinian would see the categories of the human mind as a result of the process of natural selection and so fashioned by the physical world. This view gives realism a new underpinning. For example, if we have come to be what we are, both physiologically and psychologically, in response to the adaptive pressures of natural selection, then in many respects we must accurately mirror a physical world that really exists. Just as the human ear has evolved in response to the existence of sound and the eye to the existence of light. According to this view, any universality in our innate categories of thought, could be associated with the universality of the 'Laws of Nature'.

Fitness is a concept that has been appropriated by thinkers of all disciplines. Indeed, one might apply it to the subject matter of this chapter. Of all the primitive ideas that people held about the world, those notions that attributed the earth's functional harmony and its regularity, to some form of supernatural legislation, were those ideas which people were able to exploit for their well-being and benefit. Over the centuries Man has become more sophisticated in his curiosity about Nature and in his contemplation about human thinking. he has still found certain ideas to have a persistent usefulness that are rich in application and utility.

One of these ideas is the concept of the 'Laws of Nature'. It has consistently adapted to meet the changing intellectual environment but, as in the biological realm, there is no guarantee of continual survival. The 20th century was to bring abstract ideas, and discoveries about the Universe, undreamed of by the actors in our story so far. Their successors were both led by their inheritance of the concept of the 'Laws of Nature', and challenged to refine it to its irreducible minimum by the touchstone of reality.

As our journey through history brings us up to the present time, we will find that today's theories and ideas about the origin of the universe and life, are in **as much turmoil** as they have been in the past. As we begin to delve into the what the experts and thinkers of today, have to say about the universe and its origin, I am quite sure, that many, if not most of you, will be surprised and astonished to see how much we have learnt of its secrets and yet how little we still actually know.

PART TWO

The Enigma of Time

"Then assuredly the world was made, not in time, but simultaneously with time. for that which is made in time is made both after and before some time- after that which is past, before that which is future. But none could then be past, for there was no creature, by whose movements its duration could be measured. But simultaneously with time the world was made". **St. Augustine**

In this part of the proceedings I shall present the evidence, in support of my case for the existence of a Creator. I intend to unravel certain aspects of the universe, which indicate the phenomenal and irrational odds our universe would have had to overcome, had there not been an unseen and guiding force to aide it. Without this, our universe could not have evolved into the universe we observe it to be today.

Chapter Nine

The Cosmic Clock Never Runs Backward

"Central to our feeling of awareness is the sensation of the progression of time. We seem to be moving ever forward from a definite past into an uncertain future". **Roger Penrose.**

We are all aware of the passage of time. However, our perception of the passage of time from the future into the past, is not always clear. Yet despite this we hold to the belief that the past is over, and there is nothing to be done with it. Our knowledge of time and the past may come from Prehistoric and historical records, from our memory traces, or from our deductions of these. However, we do not tend to doubt the past.

The future, on the other hand, seems undetermined. It could turn out to be one thing or it could turn out to be another. There appears to be an 'infinite' number of possibilities for whatever the future may actually resolve it self to be. As we constantly perceive time to pass, the vast and seemingly undetermined future continually becomes realised as actuality, and thus makes its entry into the fixed past.

Sometimes we may have the feeling that we have been personally responsible somewhat, for influencing a particular line of potential future activity, after it has actually materialised and become an occurrence of the past. More often, we feel ourselves to be helpless spectators - perhaps thankfully relived of responsibility - as, inexorably, the scope of the determined past edges its way into an uncertain future.

The study of the laws of physics and mathematics however, reveal a different story. All the successful equations of physics are symmetrical in time. They can be used equally well in one direction in time as well as in the other. The past and the future seem physically to be on a completely equal footing. Newton's laws, Hamilton's equations, Maxwell's equations, Einstein's theory of 'General Relativity', Dirac's equation, the Schrodinger equation....all remain effectively unaltered if even we reverse the direction of time. (Replace the co-ordinate **t** which represents time, by **-t**.). We need uncover those physical laws which can assert the distinction between the past and the future.

If we visualise a glass of water poised on the edge of a table and then, we were to nudge it, it would immediately fall to the ground. No doubt it would shatter into many pieces, water would be splashed across a considerable area of the floor The water may then start to become absorbed into a carpet or even soak into the cracks in the wooden floorboards. In this example, our glass of water has been merely following the equations of physics. Newton's descriptions will suffice here, the atoms in the glass and in the water are individually following Newton's Laws.

Now let us run this example backwards in time. According to the time-reversibility of these equations, the water could just as well flow out from the carpet and from the cracks in the floorboards, to enter the glass which is busily constructing itself from the numerous shattered pieces. The assembled whole then jump from the floor and take a leap exactly the height of the table and come to land neatly poised on the edge of the table top where it started. All of this is also in accordance with Newton's laws, just as the falling and shattering of the glass was!

We may enquire here: Where does the energy come from, to enable the glass to be raised from the floor to the table?. The answer to this is simple! There cannot be a problem with energy because in our example in which the glass falls from the table, the energy that it gains from falling must go some where. In fact the energy of the falling glass goes into heat.

The atoms in the glass fragments, in the water, the carpet and the floorboards, will be moving around a little faster than before, as compared with the movement of the atoms in these materials when the glass was poised on the table. This increase in random activity, means the 'body' temperature of the atoms will be a little warmer than before. Through the conservation of energy, this heat energy is, in fact the same amount of energy that was lost when the glass fell from the table. Therefore the increase of energy in the form of heat gain from the fall of the glass by all the atoms concerned, is enough to be able to potentially raise the glass from the floor, and back onto the table!

It is important to realise that heat energy must be included when we consider energy conservation. The law of energy conservation, when the energy of heat is taken into account, is called the 'First Law of Thermodynamics[16]'. The first law of thermodynamics, being a deduction from Newtonian mechanics, is time - symmetrical.

Since the first law of thermodynamics, which deals with the relationship of energy transfer from one form to another and its conservation, it does not constrain the glass and water in any way which rules out its assembling itself into one piece, filling with water and jumping back miraculously on to the table.

The reason that we do not observe such things happen is that the heat motion of the atoms in the glass fragments, water, floorboards, and carpet will be all haphazard, so most of the atoms will be moving in all the wrong directions. An **'absurdly'** precise co-ordination of their motions would be needed in order to reassemble the glass together with all the splashes of water collected back in it, and further hauled up delicately up on to the table. It is certain that such effective co-ordinated motion will not be present! Such co-ordination could only be known or could actually occur, through the most amazing coincidence - a chance occurrence - the kind that would be considered sorcery or a miracle if it was ever to occur!

Yet the movement of the atoms in the other direction of time, in which the glass tumbles from the table to the floor, is a co-ordinated motion which is commonplace. Somehow, we do not regard it as a fluke if the particles are moving in a co-ordinated fashion, provided that they do it after some large scale change has taken place in the physical state (here the shattering and spilling of the glass of water), rather than before such a change. The particle motions must indeed be highly co-ordinated after such an event; for these motions are of such a nature that if we were to reverse, the motion of a single atom in a precise way, the resulting behaviour would be exactly what would be needed to reassemble, fill and lift the glass to its precise starting configuration.

Highly co-ordinated motion of atoms is acceptable and familiar if it is regarded as being an effect of a large scale change and not the cause of it. However, the words cause and effect somewhat beg the question of time-asymmetry. In our normal lives we are used to applying these terms in the sense that the cause must precede the effect. But if we are trying to understand the physical distinction between the past and the future, we have to be very careful not to inject our everyday concepts about the past and the future into the discussion unwittingly.

However, there is something else involved in our use of the cause and effect which is not really a matter of compartmentalising events into past and future time slots. Let us imagine a hypothetical universe in which the same time-symmetrical classical equations, apply as those of our own universe, but for which behaviour of the familiar kind, for example, the spilling of water in our glass, coexists with occurrences like the time-reverses of these.

Suppose that, along with our more familiar experiences, sometimes water glasses do assemble themselves out of broken pieces, mysteriously re-filling the glasses by collecting together every splash of water, and then leaping back up onto the table top.

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[16] The science of relations between heat and other forms of energy.

Suppose also that on occasion, scrambled eggs could magically unscramble and un-cook themselves, finally to leap back into broken eggshells which perfectly assemble and seal themselves, that lumps of dissolved sugar could form themselves out of sweetened coffee or tea and then spontaneously jump from the cup into someone's hand! If such occurrences were commonplace in our universe, we would no doubt attribute the causes of such occurrences to some teleological effect - that is - to some predetermined purpose, not to some mechanical law or to mere chance. The self assembly of our glass would be attributed to this effect since the objective is to strive to achieve some desired and comprehensive configuration.. No doubt we would exclaim:

> *"Look!, It's happening again. That pile of glass fragments is going to assemble itself into another glass of water!"*

We would take the view that the atoms were organising themselves extremely accurately since that was the way to re-produce the glass of water on the table. The glass on the table would be the cause and the apparently random collection of atoms on the floor would be the effect - despite the fact that the effect now occurs earlier in time than the cause. Likewise, the minutely organised motion of the atoms in our scrambled eggs is not the cause of the leap back into the assembling eggshell, but the effect of the future occurrence. Likewise the sugar lump does not assemble itself and leap out of the cup because the atoms move with such extraordinary precision, but the sugar lump forms its initial solid form because of its anticipatory occurrence in the future, that someone will hold that sugar lump in their palm.!

Of course in our world, we do not see such things happen - or rather, what we do not see is the coexistence of such events with those of our everyday kind. If what we did observe, were these sorts of events of such bizarre nature, then we would have no problem in classifying such events. We could just interchange the terms *past* and *future, before* and *after,* etc., in all our descriptions.

Time could be deemed to be progressing in the reverse direction from the one originally specified, and that bizarre universe could be described as being just like our own.

However, we are envisaging here a different possibility - just as consistent with the time-symmetrical equations of physics where shattering and self-assembling water glasses can coexist. In such a world, we cannot retrieve our familiar descriptions merely by a reversal of our conventions about the direction of progression of time.

Our world is evidently not as bizarre as this. **But why not?** To begin to understand this situation, recall that we have been trying to imagine such a world, and have wondered how we would describe the occurrences taking place within it. We should be able to accept that in our said bizarre world, we would, no doubt describe our macroscopic configurations - such as unbroken glasses of water, unscrambled eggs in their shells, lumps of sugar cubes - as providing potential causes. Our effects would subsequently be the motions of the individual atoms, whether the cause lies in the past or the future, of such effects.

Why is it that, in the world in which we happen to live, it is the cause which precede the effect. To put things in another way, why do precisely co-ordinated particle motions occur only after some large-scale change in the physical state and not before it? In order to get a better physical description of such things, we will need to introduce the concept of entropy. In simple terms, the entropy of a system is a measure of its manifest disorder. Thus, the smashed glass and spilt water on the floor had a higher state of entropy than the assembled and filled glass on the table; the scrambled egg has a higher state of entropy than the fresh unbroken egg; the sweetened coffee has a higher state of entropy than the undissolved sugar lump sitting next to unsweetened coffee. The low state of entropy seems specially ordered in some manifest way, and the higher state of entropy, less specially ordered

It is important to realise, when we refer to the ‘specialness’ of a low entropy state, that we are indeed referring to manifest ‘specialness’. In a more subtle sense, the higher entropy state, in these situations, is just as specially ordered as the lower entropy state, owing to the very precise co-ordination of the motions of the individual particles. For example, the seemingly random motions of the water molecules which have leaked between the floorboards after the glass has smashed, are indeed very special: the motions are so precise that if they were all exactly reversed then the original low entropy state, where the glass sits assembled and full of water on the table, would be recovered. (This must be the case since the reversal of all these motions would simply correspond to reversing the direction of time - according to which the glass would indeed assemble itself and jump back on to the table.) But such co-ordinated motion of all the water molecules is not the kind of ‘specialness’ that we refer to as low entropy.

Chapter Ten

The Natural Order is Chaos

"Although we talk so much about coincidence we do not really believe in it. In our heart of hearts we think better of the universe, we are certainly convinced that it is not such a slipshod. haphazard affair, that everything in it has meaning". **J. B. Priestley**

As previously mentioned entropy refers to disorder. The order which is present in the precise co-ordination of particle motions is not a manifest order, so it does not count towards lowering the entropy (disorder) of a system. Thus the order of the molecules in the spilt water does not count in this way, and therefore the entropy is high. However, the manifest order in the assembled water glass produces a low entropy value. This is because there are comparatively few different possible arrangements of particle motions which are compatible with the manifest configuration of an assembled and filled water glass. In contrast there are very many more motions which are compatible with the manifest configuration of the slightly heated water flowing between the cracks in the floorboards.

The 'Second Law of Thermodynamics' asserts that the entropy of an isolated system increases with time (or remains constant, for a reversible system). It is well that we do not count the co-ordinated particle motion as low entropy; if we did, the entropy of a system, according to that definition, would always remain a constant. The entropy concept must refer only to the manifest disorder. For a system in isolation from the rest of the universe, its total entropy increases, so if it starts off in some state with some kind of manifest organisation, this organisation will in due course, become eroded.

These manifest special features will become converted into 'useless co-ordinated particle motions. It might seem perhaps, that the 'Second Law' is like a counsel of despair, for it asserts that there is a relentless and universal physical principle, telling us that organisation is necessarily continually breaking down. We shall see later that this pessimistic conclusion is not entirely appropriate. But what precisely is the entropy of a physical system? We have seen that it is some sort of measure of the manifest disorder, but it would appear, by our use of such imprecise terms as 'manifest' and 'disorder', that the entropy concept could not really be a very clear-cut scientific quantity.

There is also another aspect of the 'Second Law' which seems to indicate a lack of precision in the concept of entropy: It is only with so-called irreversible systems that the entropy actually increases, rather than just remaining constant. What does irreversible mean? If we take into account the detailed motions of all the particles, then all systems would appear to be reversible! In practice, we should say that the glass falling from the table and smashing, or the scrambling of the egg, or the dissolving of the sugar in the coffee are all irreversible. In contrast the bouncing of a small number of particles off one another would be considered reversible, as would various carefully controlled situations in which energy is not lost into heat. Basically, the term irreversible just refers to the fact that it has not been possible to keep track of, nor to control, all the relevant uncontrolled motions referred to as heat. Thus, irreversibility seems to be merely a practical matter. We cannot **in practise** unscramble an egg, though it is a perfectly viable procedure according to the laws of mechanics. Does our concept of entropy then, depend upon what is practically achievable and what is not?

For example, consider the phase space of a gas in a box. Most of the phase space of a gas is very uniformly distributed in the box, with the particles moving around in a characteristic way that provides a uniform temperature and pressure. This characteristic type of motion is, in a sense, the most random that is possible, and it is referred to as a Maxwellian distribution. When the gas is in such a random state it is said to be in thermal equilibrium. There is an incredibly vast volume of points of phase space corresponding to thermal equilibrium; the points of this volume describe all the different detailed arrangements of positions and velocities of individual particles which are consistent with thermal equilibrium. This vast volume is one of our compartments in phase space - easily the largest of all, and it occupies almost the entire phase space!

Let us consider another possible state of the gas, say where all the gas is tucked up in one corner of the box. Again there will be many different individual detailed states, all of which describe the gas being tucked up in the same way in the corner of the box. All these states are macroscopically indistinguishable from one another, and the points of phase space that represent them constitute another compartment of the phase space. However, the volume of this compartment turns out to be far tinier than that of the states representing thermal equilibrium by a factor of about

$$10^{10^{25}}.$$

This will be the case if we take the box to be a metre cube, containing air at ordinary atmospheric pressure and temperature, when in equilibrium, and if we take the region in the corner to be a centimetre cube!

To begin to appreciate this kind of discrepancy between phase space volumes, imagine a simplified situation in which a number of balls would be distributed amongst several cells. Suppose that each cell is either empty or contains a single ball. The balls are to represent gas molecules and the cells, the different positions in the box that the molecules might occupy. Let us single out a small subset of the cells as special; these would represent the gas molecule positions corresponding to the region in the corner of the box.

Suppose, for 'definiteness', that exactly one-tenth of the cells are special - say there are **n** special cells and **9n** non-special ones. We wish to distribute **m** balls among the cells at random and find the chance that all of them lie in the special cells. If there is just one ball and ten cells (so we have one special cell) this chance is clearly one-tenth. The same holds if there is one ball and any number **10n** of cells (so **n** special cells). Thus, for a gas with just one atom, the special compartment, corresponding to the gas tucked into the corner, would have a volume of just one tenth of the entire volume of the phase space. But if we increase the number of balls, the chance that they all find their way into the special cells will decrease very considerably. For two balls, say with twenty cells (two of which are special) (**m = 2, n = 2**), the chance is **1/190**, or with one-hundred cells (with ten special) (**m = 2, n = 10**) it is **1/110**; with a very large number of cells it becomes **1/100**. Thus, the volume of the special compartment for a two atom gas is just one hundredth of the entire volume of the phase space. For three balls and thirty cells (**m = 3, n = 3**), it is **1/4060**; and with a very large number of cells it becomes **1/10000**. For five balls and a very large number of cells, the chance becomes **1/100000**, and so on. For **m** balls and a very large number of cells, the chance becomes $\mathbf{1/10^m}$, so for an m-atom gas, the volume of the special region is $\mathbf{1/10^m}$ of that of the phase space. (This is still true if momentum is included.)

We can apply this to the situation considered above, of an actual gas in a box, but now instead of being only one-tenth of the total, the special region occupies only one millionth (i.e. **1/1000000**) of this total (i.e. one cubic centimetre in one cubic metre). This means that instead of the chance being $\mathbf{1/10^m}$, it is now $\mathbf{1/(1000000)^m}$, i.e. $\mathbf{1/10^{6m}}$. For ordinary air, there would be about $\mathbf{10^{25}}$ molecules in our box as a whole, so we take $\mathbf{m = 10^{25}}$. Thus, the special compartment of phase space, representing the situation where all the gas lies tucked up in the corner, has a volume of only

$$\mathbf{1/10^{60\,000\,000\,000\,000\,000\,000\,000\,000}}$$

of that of the entire phase space!

The entropy of a state is a measure of the volume V of the compartment containing the phase-space point which represents the state. In view of the enormous discrepancies between these volumes, as noted above, it is perhaps as well that the entropy is taken not to be proportional to that volume, but to the logarithm of the volume:

$$\textbf{Entropy = k log V}.$$

Taking a logarithm, helps to make these numbers look more reasonable. The logarithm of **10 000 000**, for example, is only about 16. The quantity **k** is a constant, called Boltzmann's constant. (It values at 10^{-23} joules per degree Kelvin). The essential reason for taking a logarithm here is to make the entropy an additive quantity, for independent systems. Thus, for two completely independent physical systems, the total entropy of the two systems combined will be the sum of the entropies of each separate system[17].

The enormous discrepancies between the sizes of the compartments in phase space will look more reasonable in terms of entropy. The entropy of our cubic metre-sized box of gas, as described above, turns out to be roughly **1400 JK**$^{-1}$ (**= 14k x 10**^{25}) larger than the entropy of the gas concentrated in the cubic centimetre-sized special region (since $\mathbf{log_e}$ ($\mathbf{10^{6x10^{25}}}$) is about (**14x10**^{25}).

In order to give the actual entropy values for these compartments we should carefully consider the question of the units that are chosen (meters, joules, kilograms, degrees Kelvin, etc.).

That would be out of place here, and in fact, for the utterly stupendous entropy values that we shall be giving shortly it makes essentially no difference at all what units are in fact chosen. However, for 'definiteness' (for the experts), we shall be taking natural units, as are provided by the rules of quantum mechanics and for which Boltzmann's constant turns out to be unity.

Suppose now, that we start a system off in some very special situation, such as with the gas all in one corner of the box. The next moment the gas will spread and it will rapidly occupy larger and larger volumes. After a while it will settle into thermal equilibrium. What is our understanding of this in terms of phase space? At each stage, the complete detailed state of positions and motions of all the particles of the gas would be described by a single point in phase space. As the gas evolves, this point wanders about in the phase space area, its precise wanderings describing the entire history of all the particles of the gas. The point starts off in a very tiny region - the region which represents the collection of possible initial states of which the gas is compartmentalised in one corner of the box. As the gas begins to spread, our moving point will enter a considerably larger phase-space volume, corresponding to the states where the gas is spread out a little through the box in this way.

The phase-space point keeps entering larger and larger volumes as the gas spreads further. Each new volume totally dwarfs all the ones that the point has been in before by absolutely stupendous factors! In each case, once the point has entered the larger volume, there is (in effect) no chance that it can find any of the previous smaller ones. Finally it loses itself in the largest volume of all in the phase space - that corresponding to thermal equilibrium.

This volume practically occupies the entire phase-space. One can be virtually assured that our phase-space point, in its effectively random wanderings, will not find any of the smaller volumes in any **plausible** time. Once the state of thermal equilibrium has been reached then, to all intents and purposes, the state remains this way permanently.

Thus we see that the entropy of the system, which simply provides a logarithmic measure of the volume of the appropriate compartment in phase space, will have this inexorable tendency to increase[18] as time progresses. We now would seem to have an explanation for the Second Law! For we may suppose that our phase-space point does not move about in any particularly contrived way, and if it starts off in a tiny phase-space volume, corresponding to a small entropy, then as time progresses, it will indeed be overwhelmingly likely to move into successively larger and larger phase-space volumes, corresponding to gradually increasing entropy values. However, there is something a little odd about what we seem to have deduced through this argument.

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[17] This is a consequence of the basic algebraic property of the logarithm function: log AB = log A + log B, in their respective phase spaces, then the phase space volume for the two together will be their product AB, because each possibility for one system has to be separately counted with each possibility for the other. Hence the entropy of the combined system will indeed be the sum of the two individual entropies.

[18] Of course it is not true that our phase-space point will never find one of the smaller compartments again. If we wait long enough, comparatively tiny volumes will eventually re-enter. (This would be referred to as a Poincarii recurrence.) However, the timescales would be ridiculously long in most circumstances, e.g. about:

$$10^{10^{26}}$$

We seem to have deduced a **time-asymmetric conclusion**. The entropy increases in the positive direction in time, and therefore it must decrease in the reversed time-direction. Where has this **time-asymmetry** come from? We have certainly not introduced any time-asymmetric physical laws. The time-asymmetry comes merely from the fact that the system has been started off in a very special (i.e. low-entropy) state; and thus having started the system, we have watched it evolve in the future direction, and found that the entropy increases.

This entropy increase is **indeed in accordance** with the behaviour of systems in our **actual universe**. But we could equally have applied this very same argument in the reverse direction in time. We could again specify that the system is in a low-entropy state at 'some' given time, but now ask what is the most likely sequence of states which preceded this.

Let us try the argument in this reverse way. As before, take the low-entropy state to be the gas all in one corner of the box. Our phase-space point is now in the same tiny region that we started if off in before. But now let us try to trace it backwards in time. If we imagine the phase-space point jiggling around in a fairly random way as before, then we expect, as we trace the motion backwards in time, that it would soon reach the same considerably larger phase-space volume as before, corresponding to the gas being spread a little through the box but not in thermal equilibrium and then the larger and larger volumes. Each new volume would totally dwarf the previous ones, and back further in time we would fit it in the largest volume of all, representing thermal equilibrium.

Now we seem to have deduced that given that the gas was, at one time, all tucked up in the comer of the box, then the most likely way that it could have got there was that it started in thermal equilibrium, then began to concentrate itself over at one end of the box more and more, and finally collected itself in the small specified volume in the corner.

All the time, the entropy would have to be decreasing: it would start from the high equilibrium value, and then gradually decrease until it reached the very low value corresponding to the gas tucked in the small corner of the box!

Of course, this is **nothing** compared to what actually happens in our universe! Entropy does not decrease in this way - it increases[19]. If the gas were known to be all compressed into one corner of the box at some particular time, then a much more likely situation to precede this might have been the gas being held firmly in the corner by a partition, which was suddenly removed. Or perhaps the gas had been held there in a frozen or liquid state and was rapidly heated to become gaseous. For any of these alternative possibilities, the entropy would be even lower in the previous states.

The 'Second Law' did indeed hold sway, and the entropy was increasing all the time - i.e. in the reverse time-direction it was actually decreasing. Now we see that our argument has given us the wrong answer completely! It has told us that the most likely way to get the gas into the corner of the box would be to start from thermal equilibrium and then, with entropy steadily reducing, the gas would collect in the corner; whereas in fact, in our actual world, this is **an exceedingly unlikely** way for it to happen. In our world, the gas would start from an even less likely (i.e. lower-entropy) state, and the entropy would steadily increase to the value it subsequently has, for the gas to be tucked in the corner.

Our argument seemed to be fine when applied to the future direction but not in the past direction. For the future direction, we correctly anticipate that whenever the gas starts off in the corner, the most likely thing to happen in the future, is that thermal equilibrium will be reached, not that a partition will suddenly appear, or the gas will suddenly freeze or become liquid. Such bizarre alternatives would represent just the kind of entropy-lowering behaviour in the future direction that our phase-space argument seems correctly to rule out. But in the past direction, such 'bizarre' alternatives are indeed what would be likely to happen - and they do not seem to be at all bizarre! Our phase-space argument therefore gave us completely the wrong answer when we tried to apply it in the reverse direction of time!

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years in the case of the gas all reaching the centimetre cube in the corner of the box. This is far far longer than the time that the universe has been in existence according to the current 'Big Bang Theory'! We shall ignore this possibility in the discussion to follow, as it is not really relevant to the problem at issue.

[19] Just as our eggs do not unscramble and re-enter the eggshell which then makes itself whole again!!!

Clearly this casts doubt on the original argument. We have not deduced the Second Law. What that argument actually showed, was that for a given low-entropy state (say for a gas tucked in a corner of a box), then in the absence of any other factors constraining the system, the entropy would be expected to increase in both directions in time, away from the given state. The argument has not worked in the past direction in time precisely because there were such factors. There was indeed something constraining the system in the past. That is, something forced the entropy to be low in the past. The tendency towards high entropy in the future is no surprise. The high-entropy states are, in a sense, the 'natural' states, which do not need further explanation. But the low-entropy states in the past are a puzzle. What constrained the entropy of our world to be so low in the past? The common presence of states in which the entropy is absurdly low is an amazing fact of the actual universe that we inhabit - though such states are so commonplace and familiar to us that we do not normally regard them as amazing. We human-folk are configurations of ridiculously tiny entropy! The above argument shows that we should not be surprised if, given a low-entropy state, the entropy turns out to be higher at a later time. What should surprise us is that entropy gets more and more ridiculously tiny the farther and farther we examine it in the past!

Chapter Eleven

Cause and Effect

"Time is God's way of keeping things from happening all at once". **Anonymous**

We shall try to understand where this 'amazing' low entropy comes from in the actual world that we inhabit. Let us start with ourselves. If we can understand where our own low entropy came from, then we should be able to see where the low entropy in the gas held by the partition came from - or in the water glass on the table, or in the egg held above the frying pan, or the lump of sugar held over the coffee cup. In each case a person or a collection of people (or perhaps a chicken!) was directly or indirectly responsible. It was, to a large extant, some small part of the low entropy in ourselves which was actually made use of in setting up these other low-entropy states. Additional factors might also have been involved. Perhaps a vacuum pump was used to suck the gas to the corner of the box behind the partition. If the pump was not operated manually, then it may have been that some 'fossil fuel' (e.g. oil) was burnt in order to provide the necessary low-entropy energy for its operation.

Perhaps the pump was electrically operated, and relied, to some extent, on the low-entropy energy stored in the uranium fuel of a nuclear power station. We shall return to these other low-entropy sources later, but let us first just consider the low entropy in ourselves.

Where indeed does our own low entropy come from? The inherent organisation in our bodies comes from the food that we eat and the oxygen that we breath. Often one hears it stated that we obtain energy from our intake of food and oxygen, but that is not really correct. It is true that the food we consume does combine with this oxygen that we take into our bodies, and that this provides us with energy. But for the most part, this energy leaves our bodies again, mainly in the form of heat. Since energy is conserved, and since the actual energy content of our bodies remains more-or-less constant throughout our adult lives, there is no need simply to add to the energy content of our bodies. We do not need more energy in our bodies than we already have. In fact we add to our energy content when we put on weight - but that is usually not considered desirable! Also, as we grow up from childhood we increase our energy content considerably as we build up our bodies; this is not what we are concerned about here. The question is how we can keep ourselves alive throughout our normal (mainly adult) lives. During this phase of our lives, we do not need to build up our energy content.

However, we do need to replace the energy that we continually lose in the form of heat. Indeed, the more 'energetic' that we are, the more energy we actually lose in this form. All this energy must be replaced. Heat is the most disordered form of energy that there is, i.e. it is the highest-entropy form of energy. We take in energy in a low-entropy form (food and oxygen) and we discard it in a high-entropy form (heat, carbon dioxide, excreta). We do not need to gain energy from our environment, since energy is conserved. But we are continually fighting against the Second Law of Thermodynamics. Entropy is not conserved - it is increasing all the time. To keep ourselves alive, we need to keep lowering the entropy that is within ourselves. We do this by feeding on the low-entropy combination of food and atmospheric oxygen, combining them within our bodies, and discarding the energy, that we would otherwise have gained, in a high-entropy form. In this way, we can keep the entropy in our bodies from rising, and we can maintain (and even increase) our internal organisation.

Where does this supply of low entropy come from? If the food that we are eating happens to be meat (or mushrooms if you are a vegetarian!), then it, like us, would have relied on a further external low-entropy source to provide and maintain its low-entropy structure. That merely pushes the problem of the origin of the external low entropy to somewhere else. So let us suppose that we (or the animal or mushroom) are consuming a plant. We should all be extremely grateful for 'green plants' - either directly or indirectly - for their cleverness: Taking atmospheric carbon dioxide, separating the oxygen from the carbon, and using that carbon to build up their own substance.

This procedure, called photosynthesis, effects a large reduction in the entropy. We humans make use of this low-entropy separation by, in effect, simply recombining the oxygen and carbon within our own bodies. How is it that the green plants are able to achieve this entropy-reducing miracle? They do it by making use of sunlight. The light from the sun brings energy to the earth in a comparatively low-entropy form, namely in the photons of visible light. The earth, including its inhabitants, does not retain this energy, but (after some while) re-emits it all back into space. However, the re-emitted energy is in a high-entropy form, namely what is called ‘radiant heat’- which means infra-red photons.

Contrary to a common impression, the earth (together with its inhabitants) does not gain energy from the sun! What the earth does is to take energy in a low-entropy form, and then spew it all back again into space, but in a high-entropy form. What the sun has done for us is to supply us with a huge source of low entropy. We (thanks to the miraculous work of the plants) make use of this, ultimately extracting some tiny part of this low entropy and converting it into the remarkable and intricately organised structures that are human beings.

Let us see, from the overall point of view with regard to the sun and the earth, what has happened to the energy and entropy. The sun emits energy in the form of visible-light photons. Some of these are absorbed by the earth, their energy being re-radiated in the form of infra-red photons. Now, the crucial difference between the visible-light and the infra-red photons is that the former have a higher frequency and therefore have individually a higher energy than the latter.

This tells us that the higher the frequency of a photon, the higher will be its energy. Since visible-light photons each have higher energy than do each of the infra-red ones, there must be fewer visible-light photons reaching the earth than there are infra-red ones leaving the earth, so that the energy coming in to the earth balances that leaving it.

The energy that the earth spews back into space is spread over many more degrees of freedom than is the energy that it receives from the sun. Since there are so many more degrees of freedom involved when the energy is sent back out again, the volume of phase-space is much larger, and the entropy has gone up enormously. The green plants, by taking in energy in a low-entropy form (comparatively few visible-light photons) and re-radiating it in a high-entropy form (comparatively many infra-red photons) have been able to feed on this low entropy and provide us with this oxygen-carbon separation that we need.

All this is made possible by the fact that the sun is a hot-spot in the sky! The sky is in a state of temperature imbalance: one small region of the sky, namely that occupied by the sun, is at a very much higher temperature than the rest. This fact provides us with the required powerful low-entropy source. The earth gets energy from that hot-spot in a low-entropy form (few photons), and it re-radiates to the cold regions in a high-entropy form (many photons).

Why is the sun such a hot-spot? How has it been able to achieve temperature imbalance, and thereby provide a state of low entropy? The answer is that it has formed by gravitational contractions from a previously uniform distribution of gas (mainly hydrogen). As it contracted, in the early stages of its formation the sun heated up. It would have continued to contract and to heat up even further except that, when its temperature and pressure reached a certain point, it found another source of energy, besides that of gravitational contraction.

This being thermonuclear reactions, which is the fusion of hydrogen nuclei into helium nuclei to provide energy. Without thermonuclear reactions, the sun would have got a lot more hotter and smaller than it is now, until finally it would have died out. Therefore thermonuclear reactions have actually kept the sun from getting too hot, by stopping it from contracting further, and have stabilised the sun at a temperature that is suitable for human life, enabling it to continue shining for far longer than it could otherwise have done.

It is important to realise that although thermonuclear reactions are undoubtedly highly significant in determining the nature and the amount of radiated energy from the sun, it is gravitation that is the crucial consideration[20]. Without gravity, the sun would not even exist! The sun would still shine without thermonuclear reactions - though not in a way suitable for us - but there could be no shining sun at all, without the gravity that is needed in order to hold its material together and to provide the temperatures and pressures that are needed. Without gravity, there would be merely a cold, diffuse gas in place of the sun and there would be no hot-spot in the sky! We have not yet discussed the source of the low entropy in the 'fossil fuels' in the earth; but the considerations are basically the same. According to the conventional theory, all the oil (and natural gas) in the earth comes from prehistoric plant life. Again, it is the plants which are found to be responsible for this source of low entropy. The prehistoric plants received their low entropy from the sun - so it is the gravitational action in forming the sun out of a diffuse gas, that we must again turn to.

What about the low-entropy nuclear energy in the uranium^{-235} isotope that is used in nuclear power stations? This did not come originally from the sun (though it may well have passed through the sun at some stage) but from some other star, which exploded many thousands of millions of years ago in a supernova explosion! Actually, the material was collected from many such exploding stars.

The material from these stars were scattered into space by the explosion, and some of it eventually collected together (through the agency of the sun) to provide the heavy elements in the earth. Each nucleus, with its low-entropy store of energy, came from the violent nuclear processes which took place in some supernova explosion. The explosion occurred as the aftermath of the gravitational collapse of a star that had been too massive to be able to hold itself apart by thermal pressure forces.

As the result of that collapse and subsequent 'explosion', a small core remained - probably in the form of what is known as a neutron star. The star would have originally contracted gravitationally from a diffuse cloud of gas, and much of this original material, including our uranium^{-235}, would have been thrown back into space. However, there was a huge gain in entropy due to gravitational contraction because of the neutron-star core that remained. Again it was gravity that was ultimately responsible - this time causing the (finally violent) condensation of diffuse gas into a neutron star.

We seem to have come to the conclusion that all the remarkable 'lowness' of entropy that we find about us - and which provides this most puzzling aspect of the 'Second Law' - must be attributed to the fact that vast amounts of entropy can be gained through the gravitational contraction of diffuse gas into stars. Where has all this diffuse gas come from? It is that fact that this gas starts off as diffuse that provides us with an enormous store of low entropy. We are still living off this store of low entropy, and will continue to do so for a long while to come. It is the potential that this gas has for gravitationally clumping which has given us the 'Second Law'. Moreover, it is not just the 'Second Law' that this gravitational clumping has produced, but something very much more precise and detailed than the simple statement: 'The entropy of the world started off very low'.

The entropy might have been given to us as 'low' in many other different ways, i.e. there might have been great 'manifest order' in the early universe, but quite different from that 'order' we have actually been presented with. (Imagine that the early universe had been a regular dodecahedron - as might have appealed to Plato - or some other improbable geometrical shape. This would indeed be 'manifest order', but not of the kind that we expect to find in the actual early universe!). We must understand where all this diffuse gas has come from - and for that we shall need to turn to our cosmological theories.

[20] In fact the potentiality for thermonuclear reactions does give a highly significant contribution to the 'lowness' of the sun's entropy, but the questions not tackled here, dealing with the entropy of fusion are delicate, and a full discussion of them would serve merely to complicate the argument without affecting the ultimate conclusion

As far as we can tell from using our most powerful telescopes - both optical and radio - the universe, on a very large scale, appears to be rather uniform but more remarkably, it is expanding. The farther away that we look, the more rapidly the distant galaxies (and even more distant quasars[21]) appear to be receding from us. It is as though the universe itself was created in one gigantic explosion - an event referred to as the 'Big Bang', which occurred some ten thousand million years ago. Impressive further support for this uniformity, and for the actual existence of the 'Big Bang', comes from what is known as the black-body background radiation.

The background radiation is thermal radiation - photons moving around randomly, without discernible source - corresponding to a temperature of about 2.7 degrees absolute (2.7 K), i.e. -270.3 degrees Celsius, or 454.5 degrees below zero Fahrenheit. This may seem like a very cold temperature - indeed it is! - but it appears to be the 'left over' of the flash of the Big Bang itself! Because the universe has expanded by such a huge factor since the time of the Big Bang, this initial fireball has dispersed by an absolutely enormous factor.

The temperatures in the Big Bang far exceeded any temperatures that can occur at the present time, but owing to this expansion, that temperature has cooled to the tiny value that the black-body background has now. The presence of this background was predicted by the Russian-American physicist and astronomer George Gamow in 1948 on the basis of the now - standard Big-Bang theory. It was first observed (accidentally) by Penzias and Wilson in 1965.

We should address a question that often puzzles people. If the distant galaxies in the universe are all receding from us, does that not mean that we ourselves are occupying some very special central location? The answer is No! The same recession of distant galaxies would be seen wherever we might be located in the universe.

The expansion is uniform on a large scale, and no particular location is preferred over any other. This is often pictured in terms of a balloon being blown up. Suppose that there are spots on the balloon to represent the different galaxies, and we take the two-dimensional surface of the balloon itself to represent the entire three-dimensional spatial universe. It is clear that from each point on the balloon, all the other points are receding from it. No point on the balloon is to be preferred, in this respect, over any other point. Likewise, as seen from the vantage point of each galaxy in the universe, all other galaxies appear to be receding from it, equally in all directions.

[21] A quasar is an extremly luminous object located in the center of some distant galaxies, which resemble stars in photographs.

Chapter Twelve

The Fountain of Chaos

"We cannot... trace the heat-history of the Universe to an infinite distance in the past. For a certain negative [that is, past] value of the time the formulae give impossible values, indication that there was some initial distribution of heat which could not have resulted, according to known 'Laws of Nature', from any previous distribution.... Now the theory of heat places us in the dilemma either of believing in ***Creation*** *at an assignable date in the past, or else of supposing that some inexplicable change in the working of natural laws then took place".* **William Jevons**

Let us return to our quest for the origin of the Second Law of Thermodynamics. We had tracked this down to the presence of diffuse gas from which the stars have condensed. What is this gas? Where did it come from? It is mainly hydrogen, but there is also about 23 per cent helium (by mass) and small quantities of other materials. According to standard theory, this gas was just spewed out as a result of the explosion which created the universe: the 'Big Bang'. However, it is important that we do not think of this as an ordinary explosion of the familiar kind, where material is ejected from some central point into a pre-existing space. Here, the space itself is created by the explosion, and there is, or was, no central point! Perhaps the situation is easiest to visualise in the positively curved case.

Consider the blown-up balloon. There is no 'pre-existing empty space' into which the material produced by the explosion pours. The space itself, i.e. the 'balloon's surface', is brought into being by the explosion. We must appreciate that it is only for visualisation purposes that our pictures, in the positively curved case, have used an 'ambient space' - the Euclidean space in which the balloon sits, or the three-dimensional space in which the 'space-time' is depicted - these ambient spaces are not to be taken as having physical reality.

The space inside or outside the balloon is there only to help us visualise the balloon's surface. It is the balloon's surface alone which is to represent the physical space of the universe. We now see that there is no central point from which the material from the 'Big Bang' emanates. The 'point' that appears to be at the centre of the balloon is not part of the universe, but is merely an aid to our visualisation of the model.

The material blasted out in the Big Bang is simply spread out uniformly over the entire spatial universe! The situation is the same (though perhaps a little harder to visualise) for the other two standard models. The material was never concentrated at any one point in space. It uniformly filled the whole of space - right from the very start! This picture underlies the theory of the hot 'Big Bang' referred to as the standard model. In this theory, the universe, moments after its creation, was in an extremely hot thermal state - the primordial fireball.

Detailed calculations have been performed concerning the nature and proportions of the initial constituents of this fireball, and how these constituents changed as the fireball (which was the entire universe) expanded and cooled. It may seem remarkable that calculations can be reliably performed for describing a state of the universe which was so different from that of our present era. However, the physics on which these calculations are based is not controversial, so long as we do not ask for what happened before about the first 10^{-4} of a second after **creation**! From that moment, one ten-thousandth of a second after creation, until about three minutes later, the behaviour has been worked out in great detail (cf. Weinberg 1977) - and, remarkably, our well-established physical theories, derived from experimental knowledge of a universe now in a very different state, are quite adequate for this.

The final implications of these calculations are that, spreading out in a uniform way throughout the entire universe, would be many photons (i.e. light), electrons and protons (the two constituents of hydrogen), some a-particles (the nuclei of helium), still smaller numbers of deuterons (the nuclei of deuterium, a heavy isotope of hydrogen), and traces of other kinds of nuclei. Perhaps also large numbers of 'invisible' particles such as neutrinos would exist, that would barely make their presence known.

The material constituents (mainly protons and electrons) would combine together to produce the gas from which stars are formed (largely hydrogen) at about 108 years after the ‘Big Bang’. Stars would not be formed at once, however. After some further expansion and cooling of the gas, concentrations of this gas in certain regions would be needed so that local gravitational effects can begin to overcome the overall expansion. Here we run into the **unresolved** and **controversial** issue of how galaxies are actually formed, and of what initial irregularities must be present for galaxy formation to be possible. I do not wish to enter into this dispute here.

Let us just accept that some kind of irregularities in the initial gas distribution must have been present, and that somehow the right kind of gravitational clumping was initiated so that galaxies could form, with their hundreds of thousands of millions of constituent stars! We have found where the diffuse gas has come from. It came from the very fireball which was the Big Bang itself. The fact that this, has been distributed remarkably uniformly throughout space, is what has given us the ‘Second Law’ - in the detailed form that this law has come to us after the entropy-raising procedure of gravitational clumping which has become available. How uniformly distributed is the material of the actual universe? We have noted that stars are collected together in galaxies. Galaxies also, are collected together into clusters of galaxies and these clusters are further collected into superclusters. There is even some evidence that these superclusters are collected into larger groupings referred to as supercluster complexes. It is important to note, however, that all this irregularity and clustering is tiny by comparison with the impressive uniformity of the structure of the universe as a whole.

The further back in time that it has been possible to see, and the larger the portion of the universe that it has been possible to survey, the more uniform the universe appears. The black-body background radiation provides the most impressive evidence for this. It tells us in particular, that when the universe was a mere million years old, over a range that has now spread to some 10^{23} kilometres - a distance from us that would encompass some 10^{10} galaxies - the universe and all its material contents were uniform (cf. Davies et al. 1987). The universe, despite its violent origins, was indeed very uniform in its early stages. Thus, it was the initial fireball that has spread this gas so uniformly throughout space.

It is here that our search has led us. Has our search come to its end? Is the puzzling fact that the entropy in our universe started out so low - the fact which has given us the Second Law of thermodynamics - to be ‘explained’ just by the circumstance that the universe started with a ‘Big Bang’? A little thought suggests that there is something of a paradox involved with this idea. It cannot really be the answer. Recall that the primordial fireball was a thermal state - a hot gas in expanding thermal equilibrium. Recall also, that the term ‘thermal equilibrium’ refers to a state of maximum entropy. (This was how we referred to the maximum entropy state of a gas in a box.)

However, the ‘Second Law’ demands that in its initial state, the entropy of our universe was at some sort of minimum, not at a maximum! What has gone wrong? One ‘standard’ answer would run roughly as follows: True, the fireball was effectively in thermal equilibrium at the beginning, but the universe at that time was very small. The fireball represented the state of maximum entropy that could be permitted for a universe of that tiny size, but the entropy permitted would have been minute in comparison with that which is allowed for a universe of the size that we find it in today. As the universe expanded, the permitted maximum entropy increased with the universe’s size, but the actual entropy in the universe lagged well behind this permitted maximum.

The ‘Second Law’ arises because the actual entropy is always striving to catch up with this permitted maximum. However, a little consideration tells us that this cannot be the correct explanation. If it were, then in the case of a (spatially closed) universe model which ultimately recollapses to a big crunch, the argument would ultimately apply again but in the reverse direction in time. When the universe finally reaches a tiny size, there would again be a low ceiling on the possible entropy values. The same constraint which served to give us a low entropy in the very early stages of the expanding universe should apply again in the final stages of the contracting universe. It was a low-entropy constraint at ‘the beginning of time’ which gave us the ‘Second Law’, according to which the entropy of the universe is increasing with time. If this same low-entropy constraint were to apply at ‘the end of time’, then we should find that there would have to be gross conflicts with the ‘Second Law of Thermodynamics’! Of course, it might well be the case that our actual universe never recollapses in this way.

Perhaps we are living in a universe with zero overall spatial curvature (Euclidean case) or negative curvature (Lobachevsky case). Or perhaps we are living in a (positively curved) recollapsing universe, but the recollapse will occur at such a remote time that no violation of the ‘Second Law’ will be discernible to us at our present epoch - despite the fact that, according to this view, the entire entropy of the universe would eventually turn around and decrease to a tiny value - and the ‘Second Law’ , as we understand it today, would be grossly violated. In fact, there are very good reasons for doubting that there could be such a turn-around of entropy in a collapsing universe. Some of the most powerful of these reasons have something to do with those mysterious objects known as ‘Black holes’. In a ‘Black hole’, we have a microcosm of a collapsing universe; so if the entropy were indeed to reverse in a collapsing universe, then observable gross violations of the ‘Second Law’ ought also to occur in the neighbourhood of a black hole. However, there is every reason to believe that, with Black holes, the ‘Second Law’ **powerfully holds sway**.

The theory of ‘Black holes’ provides a vital element to our discussion of entropy, so it will be necessary for us to consider these mysterious entities in a little detail.

What is a black hole? It is a region of space -or of ‘space-time’ within which the gravitational field has become so strong that even light cannot escape from it. It is an implication of the principles of relativity that the velocity of light is the limiting velocity: no material object or signal can exceed the local light speed. Hence, if light cannot escape from a black hole, nothing can escape. Perhaps the reader is familiar with the concept of escape velocity. This is the speed which an object must attain in order to escape from some massive body. Suppose that body were the earth, then the escape velocity from it would be approximately 40 000 kilometres per hour, which is about 25 000 miles per hour.

A stone which is hurled from the earth’s surface (in any direction away from the ground), with a speed exceeding this value, will escape from the earth completely (assuming that we ignore the effects of air resistance). If it was hurled with less speed, then it will fall back to the earth. (Thus, it is not true that ‘everything that goes up must come down’; an object returns only if it is thrown with less than the escape velocity!) For Jupiter, the escape velocity is 220 000 kilometres per hour, i.e. about 140 000 miles per hour; and for the sun it is 2 200 000 kilometres per hour, 1400 000 miles per hour. Now suppose we imagine that mass were concentrated in a sphere of just one quarter of its present radius, then we should obtain an escape velocity which is twice as great as its present value If the sun were even more concentrated, say in a sphere of one-hundredth of its present radius, then the velocity would be ten times as great. We can imagine that for a sufficiently massive and concentrated body, the escape velocity could exceed even the velocity of light! When this happens, we have a black hole.

Consider now what theory tells us will be the ultimate fate of our sun. The sun has been in existence for some five thousand million years. In another five - six thousand million years it will begin to expand in size, swelling inexorably outwards until its surface reaches to about the orbit of the earth. It will then have become a type of star known as a red giant. Many red giants are observed elsewhere in the heavens, two of the best known being Aldebaran in Taurus and Betelgeuse in Orion. All the time its surface is expanding, there will be, at its very core, an exceptionally dense small concentration of matter which will continue to grow steadily.

This dense core will have the nature of a white dwarf star. White dwarf stars, when on their own, are actual stars whose material is concentrated to extremely high density, such that a Ping-Pong ball filled with their material would weigh several hundred tonnes! Such stars are observed in the heavens, in quite considerable numbers: perhaps some ten per cent of the luminous stars in our Milky Way galaxy are white dwarfs. The most famous white dwarf is the companion of Sirius, whose alarmingly high density had provided a great observational puzzle to astronomers in the early part of this century. Later however, this same star provided a marvellous confirmation of physical theory (originally by R. H. Fowler, in around 1926) - according to which, some stars could indeed have such a large density, and would be held apart by 'electron degeneracy pressure'.

This means that it is Pauli's quantum-mechanical exclusion principle, as applied to electrons, that is preventing the star from collapsing gravitationally inwards. Any red giant star will have a white dwarf at its core, and this core will be continually gathering material from the main body of the star. Eventually, the red giant will be completely consumed by this parasitic core, and an actual white dwarf - about the size of the earth - is all that will remain. Our sun will be expected to exist as a red giant for only a few thousand million years. Afterwards, in its last 'visible' incarnation - as a slowly cooling dying ember of a white dwarf - the sun will persist for a few more thousands of millions of years, finally obtaining total obscurity as an invisible black dwarf. Not all stars would share the sun's fate.

For some stars, their destiny is a considerably more violent one, and their fate is sealed by what is known as the Chandrasekhar limit: the maximum possible value for the mass of a white dwarf star. According to a calculation performed in 1929 by Subrahmanyan Chandrasekhar, white dwarfs cannot exist if their masses are more than about one and one-fifth times the mass of the sun. (He was a young Indian who was later to become a research student, and, who was travelling on the boat from India to England when he made his calculation!) The calculation was also repeated independently in about 1930 by the Russian Lev Landau. The modern somewhat refined value for Chandrasekhar's limit is about 1.4 M• where M• is the mass of the sun, i.e. M• = one *solar mass*. Note that the Chandrasekhar limit is not much greater than the sun's mass, whereas many ordinary stars are known whose mass is considerably greater than this value. What would be the ultimate fate of a star of mass 2M•, for example? Again, according to established theory, the star would swell to become a red giant, and its white-dwarf core would slowly acquire mass just as before.

However, at some critical stage the core will reach Chandrasekhar's limit, and Pauli's exclusion principle will be insufficient to hold it apart against the enormous gravitationally induced pressures. At this point, or thereabouts, the core will collapse catastrophically inwards, and hugely increased temperatures and pressures will be encountered. Violent nuclear reactions would take place, and an enormous amount of energy would be released from the core in the form of neutrinos. These would heat up the outer regions of the star, which would have been collapsing inwards, and a stupendous explosion would ensue. The star now has become a supernova! What then happens to the still-collapsing core?

Theory tells us that it would reach enormously greater densities even than those alarming ones already achieved inside a white dwarf. The core would then stabilise as a neutron star, where now it would be neutron degeneracy pressure - i.e. the Pauli principle applied to neutrons - that is holding it apart.

The density would be such that a Ping-Pong ball containing neutron star material would weigh as much as the asteroid Hermes (or perhaps Mars's moon Deimos). This is the kind of density found inside the very nucleus itself[22]! But there is now a new limit, analogous to Chandrasekhar's (referred to as the Landau-Oppenheimer-Volkoy limit), whose modern (revised) value is very roughly 2.5 M•, above which a neutron star cannot hold itself apart.

What happens to this collapsing core if the mass of the original star is great enough that even this limit will be exceeded?

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[22] A neutron star is like a huge atomic nucleus, perhaps some ten kilometres in radius, which is, however, extremely tiny by stellar standards!

Many stars are known, of masses ranging between 10 M• and 100 M•, for example. It would seem highly unlikely that they would invariably throw off so much mass that the resulting core necessarily lies below this neutron star limit.

The expectation is that, instead, a 'Black hole' will result. The 'Second Law' will hold sway just as much inside a black hole as it does elsewhere. To understand how the entropy in a 'Big Crunch' can indeed be enormously high, as opposed to the entropy in the 'Big Bang' (which had to have been much lower), we shall need to delve a little more deeply into the 'space-time' geometry of a black hole.

A spherical surface, made up of particles falling freely in the gravitational field of some large body, would be stretched in one direction (along the line towards the gravitating body) and squashed in directions perpendicular to this. This tidal distortion increases as the gravitating body is approached, varying inversely with the cube of the distance from it. Such an increasing tidal effect will be felt by the astronaut B as he falls towards and into the black hole. For a black hole of a few solar masses, this tidal effect would be huge - far too huge for the astronaut to be able to survive any close approach to the hole, let alone to cross its horizon. For larger holes, the size of the tidal effect at the horizon would actually be smaller.

For the million solar-mass black hole that many astronomers believe may reside at the centre of our Milky Way galaxy, the tidal effect would be fairly small as an astronaut crosses the horizon, though it would probably be enough to make him feel a little uncomfortable. This tidal effect would not remain small for long. As the astronaut falls in, it would mount rapidly to infinity in a matter of seconds!! Not only would the poor astronaut's body be torn to pieces by this rapidly mounting tidal force, but in quick succession, so would the very molecules of which he was composed, their constituent atoms, their nuclei, and, finally, even all the subatomic particles! It is thus that the 'crunch' wreaks its ultimate havoc. it is not just matter that is destroyed in this way, but even the very fabric of 'space-time' must find its end! Such an ultimate catastrophe is referred to as a '**Space-Time Singularity'**.

Chapter Thirteen

Irrational Odds

"A long shot, Watson; a very long shot"! **Silver Blaze**

The reader may well ask how it is that we know such catastrophes will occur, and under what circumstances matter and 'space-time' are destined to suffer this fate. These are conclusions that follow from the classical equations of general relativity in any circumstance when a black hole is formed. The original black hole model of Oppenheimer and Snyder (1939) exhibited behaviour of this kind. However, for many years astrophysicists had entertained the hope that this singular behaviour was an artefact of the special symmetries that had to be assumed for that model. Perhaps, in realistic (asymmetrical) situations the collapsing matter might swirl around in some complicated way and then escape outwards again. But such hopes were dashed when more general types of mathematical argument became available, providing what is known as singularity theorems (cf. Penrose 1965, Hawking and Penrose 1970).

These theorems established within the classical theory of general relativity with reasonable material sources, that 'space-time' singularities are inevitable in situations of gravitational collapse. Likewise, using the reverse direction of time, we again find inevitability for a corresponding initial 'space-time' singularity which now represents the 'Big Bang' in any (appropriately) expanding universe. Here, rather than representing the ultimate destruction of all matter and 'space-time', the singularity represents the creation of 'space-time' and matter. It might appear that there is an exact temporal symmetry between these two types of singularity: the initial type, whereby 'space-time' and matter are created; and the final type, whereby 'space-time' and matter are destroyed. There is, indeed, an important analogy between these two situations, but when we examine them in detail we find that they are not exact time-reverses of one another.

The geometric differences are important for us to understand because they contain the key to the origin of the 'Second Law of Thermodynamics'! Let us return to the experiences of our astronaut B. He encounters tidal forces which mount rapidly to infinity. Since he is travelling in empty space, he experiences the volume preserving but distorting effects that are provided by the kind of 'space-time' curvature tensor that can be denoted by WEYL. The remaining part of the 'space-time' curvature tensor, the part representing an overall compression and referred to as RICCI, is zero in empty space. It might be that astronaut B does in fact encounter matter at some stage, but even if this is the case (and he is, after all, constituted of matter himself), we still generally find that the measure of WEYL is much larger than that of RICCI. We expect to find, indeed, that the curvature close to a final singularity is completely dominated by the tensor WEYL. This tensor goes to infinity, in general:

WEYL k _

(though it may well do so in an oscillatory manner). This appears to be the generic situation with a 'space-time' singularity. Such behaviour is associated with a singularity of *high entropy*. However the situation with Big Bang the appears to be quite different. The standard models of the 'Big Bang' are provided by the highly symmetrical Friedmann-Robertson-Walker 'space-times' that we considered earlier. Now the distorting tidal effect provided by the tensor WEYL is entirely absent. Instead there is a symmetrical inward acceleration acting on any spherical surface of test. This is the effect of the tensor RICCI, rather than WEYL. In any FRW-model, the tensor equation

WEYL = 0

always holds. As we approach the initial singularity more and more closely, we find that it is RICCI that becomes infinite, instead of WEYL, so it is RICCI that dominates near the initial singularity, rather than WEYL.

This provides us with a singularity of low entropy. If we examine the big crunch singularity in the exact recollapsing FRW-models, we now find WEYL = 0 at the crunch, whereas RICCI goes to infinity. However, this is a very special situation and is not what we expect for a fully realistic model in which gravitational clumping is taken into account.

As time progresses, the material, originally in the form of a diffuse gas, will clump into galaxies of stars. In due course, large numbers of these stars will contract gravitationally into white dwarfs, neutron stars, and ‘black holes’. There may well be some huge ‘black holes’ in galactic centres. The clumping -particularly in the case of ‘black holes’ - represents an enormous increase in the entropy.

It may be puzzling at first, that the lumpy states represent high entropy and the smooth ones low, when we recall that with a gas in a box, the clumped states (such as the gas being all in one comer of the box) were of low entropy, while the uniform state of thermal equilibrium was high. When gravity is taken into account there is a reversal of this, owing to the universally attractive nature of the gravitational field. The clumping becomes more and more extreme as time goes on, and at the end, many ‘black holes’ congeal, and their singularities unite in the very complicated, final, big crunch singularity. The final singularity in no way resembles the idealised big crunch of the recollapsing FRW-model, with its constraint WEYL = 0. As more and more clumping takes place, there is, all the time, a tendency for the WEYL tensor to get larger and larger and, in general, WEYL any final singularity. We see now how it is, that a re-collapsed universe need not have a small entropy.

The 'lowness' of the entropy at the ‘Big Bang’ - which gave us the ‘Second Law’ - was thus not merely a consequence of the 'smallness' of the universe at the time of the ‘Big Bang’! If we were to time-reverse the picture of the big crunch that we obtained above, then we should obtain a '‘Big Bang’' with an enormously high entropy, and there would have been no ‘Second Law’ ! For some reason, the universe was created in a very special (low entropy) state, with something like the WEYL = 0 constraint of the FRW-models imposed upon it. If it were not for a constraint of this nature, it would be much more probable to have a situation in which both the initial and final singularities were of high- entropy WEYL k _ type. In such a 'probable' universe there would indeed, be no ‘Second Law’ of Thermodynamics!

Let us try to understand just how much of a constraint a condition such as WEYL = 0 at the ‘Big Bang’ was. For simplicity (as with the above discussion) we shall suppose that the universe is closed. In order to be able to work out some clear-cut figures, we shall assume furthermore, that the number B of baryons - that is, the number of protons and neutrons taken together in the universe, is roughly given by $B = 10^{80}$. (There is no particular reason for this figure, apart from the fact that observationally, B must be at least as large as this; Eddington once claimed to have calculated B exactly, obtaining a figure which was close to the above value! No-one seems to believe this particular calculation any more, but the value 10" appears to have stuck.) If B were taken to be larger than this, then the figures that we would obtain, would be even more striking and irrational than the extraordinary figures that we shall be arriving at in a moment!

Try to imagine the phase space of the entire universe! Each point in this phase space represents a different possible way that the universe might have started off. We may imagine the **Creator**, armed with a 'pin' - which is to be placed at some point in the phase space. Each different positioning of the pin provides a different universe. Now the accuracy that is needed for the **Creator's** aim depends upon the entropy of the universe that is thereby created. It would be relatively 'easy' to produce a high entropy universe, since then there would be a large volume of the phase space available for the pin to hit[23].

But in order to start off the universe in a state of low entropy - so that there will indeed be a ‘Second Law of Thermodynamics’ - The **Creator** must aim for a much smaller volume of the space. How small would this region be, in order that one closely resembling the one in which we actually live would be the result? In order to answer this question, we must first turn to a very remarkable formula, provided by Jacob Bekenstein (1972) and Stephen Hawking (1975), which tell us what the entropy of a black bole must be. Consider a black hole, and suppose that its horizon's surface area is A. 'The Bekenstein-Hawking formula for the black hole's entropy is then:

$$\mathbf{S_{bh} = A/4 \times (kc^3/ G\mathit{h})}$$

[23] Recall that the entropy is proportional to the logarithm of the volume of the phase space concerned

where k is Boltzmann's constant, c is the speed of light, G is Newton's gravitational constant, and *h* is Planck's constant over 2p. The essential part of this formula is the A/4. The part in parentheses merely consists of the appropriate physical constants. Thus, the entropy of a black hole is proportional to its surface area. For a spherically symmetrical black hole, this surface area turns out to be proportional to the square of the mass of the hole:

$$\mathbf{A = m^2 \times 8^1 (G^2/c^4)}$$

Putting this together with the Bekenstein-Hawking formula, we find that the entropy of a black hole is proportional to the square of its mass:

$$\mathbf{S_{bh} = m^2 \times 2^1 (kG/hc)}$$

Thus, the entropy per unit mass ($\mathbf{S_{bh}/m}$) of a black hole is proportional to its mass, and so gets larger and larger for bigger and bigger 'black holes'.

Hence, for a given amount of mass - or equivalently, Einstein's $E = mc^2$, for a given amount of energy, the greatest entropy is achieved when the material has all collapsed into a black hole! Moreover, two 'black holes' gain enormously in entropy when they mutually swallow one another up to produce a single united black hole! Large 'black holes', such as those likely to be found in galactic centres, will provide absolutely stupendous amounts of entropy - larger than the other kinds of entropy that one encounters with other types of physical situation. There is actually a slight qualification needed to the statement that the greatest entropy is achieved when all the mass is concentrated in a black hole. Hawking's analysis of the thermodynamics of 'black holes', shows that there should be a non-zero temperature also associated with a black hole. One implication of this is that not quite all of the mass - energy can be contained within the black hole, in the maximum entropy state, the maximum entropy being achieved by a black hole in equilibrium with a 'thermal bath of radiation'.

The temperature of this radiation is very small indeed for a black hole of any reasonable size. For example, for a black hole of a solar mass, this temperature would be about 10^{-7} K, which is somewhat lower than the lowest temperature that has been measured in any laboratory to date, and considerably lower than the 2.7 K temperature of intergalactic space. For larger 'black holes', the Hawking temperature is even lower! The Hawking temperature would become significant for our discussion only if either: (i) much smaller 'black holes', referred to as mini-'black holes', were to exist in our universe; or (ii) the universe does not recollapse before the Hawking evaporation time - the time according to which the black hole would evaporate away completely. With regard to (i), 'mini-black holes' could only be produced in a suitably chaotic 'Big Bang'. Such mini-black holes cannot be very numerous in our actual universe, or else their effects would have already been observed. Moreover, according to the viewpoint that we are expounding here, they ought to be absent altogether. Regarding (ii), considering a solar-mass black hole, the Hawking evaporation time would be some 10^{11} times the present age of the universe, and for larger 'black holes', it would be considerably longer.

It would not appear that these effects would substantially modify the above arguments. To get some feeling for the hugeness of black-hole entropy, let us consider what was previously thought to supply the largest contribution to the entropy of the universe, namely the 2.7 K black-body background radiation. Astrophysicists had been struck by the enormous amounts of entropy that this radiation contains, which is far in excess of the ordinary entropy that one encounters in other processes (e.g. in the sun). The background radiation entropy is something like 10^8 for every baryon[24] (where we are now choosing 'natural units', so that Boltzmann's constant is unity). (In effect, this means that there are 10^8 photons in the background radiation for every baryon.) Thus, with 10^{80} baryons in all, we should have a total entropy of

$$10^{88}$$

[24] A class of elementary particles that have a mass greater than, or equal to that of the proton.

for the entropy in the background radiation in the universe. Indeed, were it not for the ‘black holes’, this figure would represent the total entropy of the universe, since the entropy in the background radiation swamps that in all other ordinary processes. The entropy per baryon in the sun, for example, is of order unity. On the other hand, by black-hole standards, the background radiation entropy is utter 'chicken feed'. For the Bekenstein-Hawking formula tells us that the entropy per baryon in a solar-mass black hole is about 10^{20}, in natural units, so had the universe consisted entirely of solar-mass ‘black holes’, the total figure would have been very much larger than that given above, namely

$$10^{100}.$$

Of course, the universe is not so constructed, but this figure begins to tell us how 'small' the entropy in the background radiation must be when the relentless effects of gravity begin to be taken into account.

Let us try to be a little more realistic. Rather than populating our galaxies entirely with ‘black holes’, let us take them to consist mainly of ordinary stars - some 10^{11} of them - and each to have a million (i.e. 10^{6}) solar-mass black hole at its core (as might be reasonable for our own Milky Way galaxy). Calculation shows that the entropy per baryon would now be actually somewhat larger even than the previous huge figure, namely now 10^{21}, giving a total entropy in natural units, of

$$10^{101}$$

We may anticipate that after a very long time, a major fraction of the galaxies' masses will be incorporated into the ‘black holes’ at their centres. When this happens, the entropy per baryon will be 10^{31}, giving a monstrous total of

$$10^{111}$$

However, we are considering a closed universe so eventually it should recollapse; and it is not unreasonable to estimate the entropy of the final crunch by using the Bekenstein-Hawking formula as if the whole universe had formed a black hole. This gives an entropy per baryon of 10", and the absolutely stupendous total, for the entire big crunch would be

$$10^{123}.$$

This figure will give us an estimate of the total phase-space volume V available to the **Creator**, since this entropy should represent the logarithm of the volume of the (easily) largest compartment. Since 10^{123} is the logarithm of the volume, the volume must be the exponential of 10^{123}, i.e.

$$V = 10^{10^{123}}$$

in natural units (Some perceptive readers may feel that we should have used the figure $e^{10^{123}}$ but for numbers of this size, the e and the 10 are essentially interchangeable!) How big was the original phase-space volume W that the **Creator** had to aim for in order to provide a universe compatible with the ‘Second Law’ of Thermodynamics and with what we now observe? It does not matter much whether we take the value $W = 10^{10^{101}}$ or $W = 10^{10^{88}}$, given by the galactic ‘black holes’ or by the background radiation respective, or a much smaller figure (and in fact more appropriate) which would have been the actual figure at the Big Bang. Either way, the ratio of V to W will be closely

$$V/W = 10^{10^{123}}$$

This now tells us how precise the **Creator's** aim must have been: namely to an accuracy of one part in $10^{10^{123}}$. The precision needed to set the universe on its course is seen to be in no way inferior to all that extraordinary precision that we have already become accustomed to in the superb dynamical equations (Newton's, Maxwell's, Einstein's) which govern the behaviour of things from moment to moment. But why was the 'Big Bang' so precisely organised, whereas the 'Big Crunch' (or the singularities in 'black holes') would be expected to be totally chaotic? It would appear that this question can be phrased in terms of the behaviour of the WEYL part of the 'space-time' curvature at 'space-time' singularities. What we appear to find is that there is a constraint WEYL = 0 (or something very like this) at initial 'space-time' but not at final singularities - and this seems to be what confines the **Creator's** choice to this very tiny region of phase space.

The assumption that this constraint applies at any initial (but not final) 'space-time' singularity, is termed by Roger Penrose as 'The WEYL Curvature Hypothesis'. Thus, it would seem, we need to understand why such a time-asymmetric hypothesis should apply if we are to comprehend where the 'SECOND LAW' has come from. How can we gain any further understanding of the origin of the 'SECOND LAW' ? We seem to have been forced into an impasse. We need to understand why 'space-time' singularities have the structures that they appear to have but 'space-time' singularities are regions where our understanding of physics has reached its limits. The impasse provided by the existence of 'space-time' singularities is sometimes compared with another impasse: that encountered by physicists early in the century, concerning the stability of atoms. In each case, the well-established classical theory had come up with the answer 'infinity', and had thereby proved itself inadequate for the task.

You may well be asking what good our journey has done us. In our quest for understanding why time seems to flow in just one direction and not in the other, we have had to travel to the very ends of time, and where the very notions of space and time have dissolved away. What have we learnt from all this? We have learnt that our theories are not yet adequate to provide answers, but what does all this do in our attempts to understand the 'Fundamental Questions'? Despite the lack of an adequate theory, I believe that there are indeed important lessons that we can learn from our journey.

The most important lessons to be learnt are that, for this universe to exist the way we observe it today, with the arrow of time only pointing in one direction, namely the future direction, the universe would have to be able to overcome incredible odds to the order of 1 in $\mathbf{10^{10^{123}}}$. This is an **extraordinary** figure.

One could not possibly even write the number down in full, in the ordinary mundane notation: it would be 'l' followed by 10^{123} successive '0's! Even if we were to write a '0' on each separate proton and on each separate neutron in the entire universe - and we could throw in all the other particles as well for good measure - we should fall far short material for just writing down the figure needed. For those not clear what magnitude we are talking about let me elaborate further:

'l' followed by just 10^2 (100) successive '0's =

10 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000
000 000 000 000 000 000 000 000 000 000 000 000 000

'l' followed by 10^3 (1000) successive '0's =

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‘l’ followed by 10^4 (10000) successive '0's would be 10 times the last big number and fill 5 or so pages, and so on...

Having presented these overwhelming odds, I shall now proceed to the final part of our proceedings by calling forward prominent experts from their respective fields of Physics, Mathematics, Cosmology, Astronomy, Chemistry, Biology, Theology and Philosophy, to present their case for and against the need or existence of a **Creator.**.

PART THREE

Call Forth Your Witnesses!

"As physicists probe further and deeper into outer space and subatomic particles and as they learn more about the universe, they are moved closer to accepting the existence of a supreme intelligence which must be behind it all". **Anonymous**

It seems as if we have come to the end of a very long journey. Now we will see what conclusion others who have embarked on this same journey have made, and what answers if any to the 'Fundamental Questions' they have found. But more importantly see, what conclusions we can make from our journey and from their testimonies.

Remember, the answers to these questions will mould the thoughts and concepts we have about life and death, about what proceeds this life and what possibly comes after. It is these concepts we will carry, that will shape the way we conduct our lives.

Chapter Fourteen

An Intelligence on a Higher Plane

"The origin of the universe requires an intelligence, an intelligence on a higher plane, an intelligence that preceded us and that has led to a deliberate act of creation of structures suitable for life". **Fred Hoyle**

In his book, The Seven Mysteries of life, Guy Murchie states:

> *"It is easy to see why modern physicists, who have been pushing the frontier of knowledge into the unknown probably more profoundly than any other scientists in recent centuries, are ahead of most of their fellows in accepting that all-encompassing mystery of the universe commonly referred to as God".*

Astrophysicist George Greenstein, in his book, The Symbiotic Universe, says:

> *"To detail what can only seem to be an astonishing sequence of stupendous and unlikely accidents that paved the way for life's emergence. There is a list of coincidences, all of them essential to our existence".*

As Greenstein examined the evidence of the universe, the list of coincidences got longer and harder to explain by chance...

> *"Is it possible, that suddenly, without intending to we have stumbled upon scientific proof of the existence of a Supreme Being? Was it God who stepped in and so providentially crafted the cosmos for our benefit"?*

Lewis Thomas writes in Discover magazine:

> *"We perceived the order in surprise, and our cosmologists and physicists continue to find new and astonishing aspects of the order... We used to say it was a miracle, and we still permit ourselves to refer to the whole universe as a marvel."*

James Jean proclaimed:

> *"The universe appears to have been designed by a pure mathematician and it begins to look more like a great thought than a great machine".*

He goes on to say:

> *"We discover that the universe shows evidence of a designing or controlling power ... the tendency to think in the way which, for want of a better word, we describe as mathematical".*

H. S. Lipson, realising the odds against the spontaneous origin of the universe and life, said:

> *"The only acceptable explanation is creation. I know that this is anathema to physicists, as indeed it is to me, but we must not reject a theory that we do not like if the experimental evidence supports it."*

Chandra Wickramasingh, professor at University College, Cardiff, said:

> *"From my earliest training as a scientist I was very strongly brainwashed to believe that science cannot be consistent with any kind of deliberate creation. That notion has had to be very painfully shed. I am quite uncomfortable in the situation, the state of mind I now find myself in. But there is no logical way out of it...There is no other way in which we can understand the precise ordering of chemicals of life except to invoke the creation on a cosmic scale."*

Former astronaut John Glenn noted the motion of the planets and stars and observed that they were travelling in prescribed orbits in relation to one another. This led him to ask:

> *"Could this have just happened? Was it an accident that a bunch of flotsam and jetsam suddenly started making these orbits of its own accord? I can't believe that...Some Power put all this into orbit and keeps it there."*

Astrophysicist Wernher von Braun whose speciality is space rocket technology says:

> *"The natural laws of the universe are so precise that we have no difficulty building a spaceship to fly to the moon and can time the flight with the precision of a fraction of a second. These laws must have been set by somebody."*

Astrophysicist and writer John Gribbins admitted in a New Scientist article 16/8/1979:

> *"[Scientists] claim, by and large, to be able to describe in great detail what happened after this 'moment'[the big bang], what brought about 'the instant of creation' remains a mystery....maybe God did make it, after all."*

Stephen Hawkings noted in the New York Times Magazine:

> *"The more we examine the universe, we find it is not arbitrary at all but obeys certain well-defined laws that operate in different areas. It seems very reasonable to suppose that there may be some unifying principles, so that all laws are part of some bigger law."*

Dietrick E. Thomsen writer for Science News says:

> *Contemplation of these things disturbs cosmologists because it seems as if such particular and precise conditions could hardly have arisen at random. One way to deal with the question is to say the whole thing was contrived and lay it on Divine Providence."*

Paul Davies Professor of Mathematical Physics at the University of Adelaide emphatically states:

> *"We, who are children of the universe* - *animated stardust* - *can nevertheless reflect on the nature of that same universe, even to the extent of glimpsing the rules on which it runs, How we have become linked into this cosmic dimension is a mystery. Yet the linkage cannot be denied.....I cannot believe that our existence in this universe is a mere quirk of fate, an accident of history, an incidental blip in the great cosmic drama. Our involvement is too intimate."*

He goes on to say:

> *"The physical species Homo may count for nothing, but the existence of the mind in some organism on some planet in the universe is surely a fact of fundamental significance. this can be no trivial detail, no minor by-product of mindless, purposeless forces. We are truly meant to be here."*

Timothy Ferris in his article *The Other Einstein*, quotes Albert Einstein as saying:

> *"What I see in nature is a magnificent structure that we can comprehend only very imperfectly, and that must fill a thinking person with a feeling of 'humility.' This is a genuinely religious feeling that has nothing to do with mysticism.... My religiosity consists in a humble admiration of the infinitely superior spirit that reveals itself in the little that we, with our weak transitory understanding, can comprehend of reality....I want to know how God created this world".*

From the statements of all the above experts it should be clear that the subject of the origin of the universe from the scientific point of view is not as clear cut as many people think or would like to have us believe! So what conclusions if any can we derive from science if any.

The problem was very aptly summarised by astrophysicist John D Burrow in his book *The Origin of The Universe* where he comments on the various theories:

> *"None of these 'principles' concerning the origin of the universe is particularly recommended as the way to solve the greatest problem of cosmology. All are highly speculative. They are ideas for ideas...These limitations raise a big question mark over the utility of grand principles about the initial state of the universe."*

Most physicists come to the same conclusion as Burrows who ends by saying:

> *"One day we may be able to say something about the origins of our own cosmic neighbourhood...But we can* ***never*** *know the origins of the universe. The deepest secrets are the ones that keep themselves."*

So the testimony of the scientists remains inconclusive or rather a lack of will to state the obvious conclusion of a universe with a ‘Divine’ origin. For whatever cause, valid or not, we still find inescapable the impression of a ‘Designer’ or ‘Lawgiver’ behind the laws and structures of this universe. Nowhere have we discovered lawlessness, not even in the unpredictable systems studied by chaos scientists, where there is mysterious, beautiful pattern and structure. Even our depressing vision of a universe running down in an inexorable increase in entropy is being replaced by a picture that also shows us self-organisation on every scale.

We have come full circle more than once in our search for the secrets of the universe. Just as in the past our ancestors found God in the chaos of nature, later the rationality, the pattern, the legality of the universe seemed eloquent testimony of the existence of God. Then we found some scientists postulating that the universe hardly needed a God. Everything operated like clockwork, a clockwork perhaps even capable of having invented itself. It seemed that if there were a God we must return the more ancient way of looking for him in the places where the clockwork broke down or skipped a beat, in the unpredictable, the places science chose to ignore, did not yet understand - the gaps. However, science turned its searchlight on those areas too, and it looked as though there soon would be no gaps left in which we could conceive of God existing and exerting his power in the universe.

Now we discover to our surprise that the clockwork breaks down nearly everywhere. Predictable systems are the exception, not the rule. In fact, we hardly find them at all except for rather specialised situations, and then they are predictable only to a limited extent. Yet we have not discovered irrationality, and the fact we haven’t - that the universe ***is*** rational - suddenly begins to look as though it may be as difficult to explain as our ancestors thought it was.

What right have we to expect that the universe should have organised itself into galaxies, stars and planets against astronomical and absurd odds. That life on this earth would have organised itself into ecosystems, animals and human beings into societies.

You will begin to understand the statements of the above experts as it becomes ever more likely that the universe couldn’t exist without a mysterious tendency to organise itself.

Richard P Feynman writes in *The Character of Physical Law*:

> *“What is it about nature that lets this happen [make scientific predictions], that it is possible to guess from one part what the rest is going to do? That is an unscientific question: I do not know how to answer it, and therefore I am going to give an unscientific answer. I think it is because nature has simplicity and therefore a great beauty.*

Who or what is ‘Nature’? Did this system itself evolve from less effective systems? Can it all be explained as the outcome of probabilities - a statistical context mysteriously laid down at the origin of the universe.

Is there a mysterious organising principle at work, one which science will discover - or perhaps one which is beyond the power of any scientific ‘Theory of Everything’ to explain? Which then speaks more eloquently on behalf of there being a God - the pattern and rationality of the universe, or what seems unexplainable and arbitrary?

In the present context, even for those who do not believe in God, the attempts which try to explain the universe without a God begin to look slightly contrived and self-serving, and the older, simpler, more mysterious explanation, “There is a God’ less so.

The ultimate answers to all our question, the conclusions we reach will have profound repercussions on how we lead our lives. No honest agnosticism, no stark atheism, no brilliantly successful scientific explanations, no inconsistency between science and belief can cause God not to exist, if there is a God.

In the intellectual exploration we’ve undertaken in this book, we’ve found that the choices of what we should accept from science and from religion are not as starkly different as they have often been depicted.

Joseph Ford has said:

> *“more than most, [scientists] are content to live with unanswered questions.”*

John Burrows writes:

> *"There is no formula that can deliver all truth, all harmony, all simplicity. No 'Theory of Everything' can ever provide total insight. For, to see through everything would leave us seeing nothing at all."*

Religion is far more optimistic than science, that in some manner beyond our present concept of human reason, we can know 'everything important'.

In my introduction I discussed the concept of an 'Infinite God'. In our quest for ultimate answers, it is hard not to be drawn, in one way or another, to the 'infinite'. Whether it is an infinity of parallel universes, an infinite set of mathematical propositions, or an infinite Creator, physical existence surely cannot be rooted in anything finite.

When I say that God is infinite, I am primarily concerned with demonstrating that he is not limited in any way. The mathematical concept of infinity needs to be clarified, as it was generally believed that infinity is a limit towards which an enumeration may proceed, but which is unachievable in reality i.e. nothing was truly infinite - not even God.

The belief that infinity was paradoxical and self-contradictory persisted until the nineteenth century. At this stage the mathematician George Cantor, demonstrated the self-consistency of the actually infinite.

One may wonder if infinity can be grasped and manipulated using rational thought, does this open the way to an understanding of the ultimate explanation of things without the need for God and religion?

No, it doesn't! To see why let us look at the concept of infinity more closely. One of the surprises of Cantor's work is that there is not just one infinity but many. For example, the set of all integers and the set for all fractions are both infinite sets. The interesting thing is when we consider combining all infinite sets into one superset. This has been called 'Canton's Absolute'. The problem is that, this superset can't itself really be a set otherwise it would have to include itself. This problem of self-referencing leads to a paradox that was first observed by the mathematician Kurt Gödel.

The paradox was a severe blow to mathematicians who had formerly held the view that mathematics always consisted of statements which would determine whether they are true or false. This was a theorem with a vengeance, because it provided an **irrefutable** proof that something's in mathematics are actually impossible, even in principle. The fact that there exist undecidable propositions in mathematics came as a great shock as it undermined the entire logical foundation of the subject. The crux of the problem can be demonstrated by one example of a self-referential paradox.

> *"This statement is false"*

If the following statement is proved to be true it has to be false, and if it is proved false then it has to be true. The problem is therefore determining whether the statement is either true or false.

The great mathematician and philosopher Bertrand Russell held that such self-referencing paradoxes strike at the heart of logic itself.

What this paradox means in simple terms is that, we cannot know 'Canton's Absolute', or any other 'Absolute', by rational means, for any 'Absolute', being a Unity and hence complete within itself, must include itself. Mathematician Rudy Rucker in his book *Infinity and the Mind* remarks:

> *"If the Mindscape (The class of all sets of ideas) is a One[infinite], then it is a member of itself, and thus can only be known through a flash of mystical vision. No rational thought is a member of itself, so no rational thought could tie [comprehend] the Mindscape into a One."*

If science and even mathematical logic are not able to give a conclusive picture where does that leave our search? If we probe into the questions which have most vexed generations of scientists, philosophers and theologians we can find one consistent mistake which has caused them to go round in circles.

Chapter Fifteen

The Fire in the Equations

"I have always thought it curious that, while most scientists claim to eschew religion, it actually dominates their thoughts more than it does the clergy". **Fred Hoyle**

Returning back to our 'fundamental questions' of: Why are we here? What is the origin of the universe? and Does the universe have to be the way it is? We find that how we arrive at the answers is just as important as the answers themselves.

Most scientists are content to adopt the approach of the pragmatic atheist who is happy to take the universe as given and get on with cataloguing its properties. They are totally opposed temperamentally to any form of metaphysical, let alone mystical or divine arguments. They are usually scornful of the notion that there may exist a God, or even an impersonal creative principle that would underpin reality and render its contingent or dependent aspects less arbitrary.

Yet we have seen in the previous chapters that there are certainly things which are beyond our reasonable grasp, beyond the capabilities of our limited and finite brains capabilities to comprehend.

Science is built on the assumption of the rationality of the universe - and most scientists hold that things are as they are as a result of some sort of logical necessity or inevitability. In attempting to answer the fundamental questions, we have to consider the possibility of two distinct classes of things.

In the first class are facts about the universe, such as the number of planets in the solar system. It is a brute fact that there are nine planets. We can ask why there are nine and typically the explanation for why there are nine might focus on the way in which the solar system formed from a cloud of gas. Because the explanation for the features of the solar system depends on something other than itself, these features are termed 'contingent'[25].

The second class refers to facts or objects or events that are not contingent. Such things are called 'necessary'[26].

As discussed in my introduction all physical things we observe in the universe, including the universe and the events that befall them, are limited and by nature 'contingent'. Furthermore, if something were necessary, then it must always be what it is - it cannot change. A necessary thing can make no reference to time. The state of the universe continually changes with time, so all physical things that partake of that change must be contingent i.e. limited.

Some scientists hold that the universe as a whole is necessary and point to the fact that science is heading towards a super 'Theory of Everything' which will help unravel the mysteries of the universe. However some prominent experts have pointed out the limitations of such a theory if it really does exist, because of the Gödelian self-referencing Paradox discussed earlier.

Russell Stannard discussed in The Times (London) the implications and stated:

> *"A genuine theory of every thing must explain not only how our universe came into being, but also why it is the only type of universe that there could have been - why there could only be one set of physical laws.....This goal I believe to be illusory....This inherent, unavoidable lack of completeness must reflect itself in whatever mathematical system models the universe. As creatures belonging to the physical world, we will be included as part of that model. It follows that we shall never be able to justify the choice of axioms in the model - and consequently the physical laws to which those axioms correspond. Nor shall we be able to account for all true statements that can be made about the universe.*

[25] Something is contingent if it could have been otherwise, so the reason why it is the way that it is depends upon something else, something beyond itself.

[26] Something is necessary if it is what it is quite independently of anything else. A necessary thing contains the reason for itself within itself, and it would be completely unchanged if everything else were different.

The search for a genuinely unique 'Theory of Everything' that would eliminate all contingency and demonstrate that the physical world must necessarily be as it is, seems to be doomed to failure on grounds of logical consistency. No rational system can be proved both consistent and complete i.e. 'Absolute'. There will always remain some openness, some element of mystery, something unexplained.

The philosopher Thomas Torrance chides those who fall for the temptation to believe that the universe is 'some sort of *'perpetuum mobile'*, a self-existing, self-supporting, self explaining magnitude, wholly consistent and complete in itself and thus not requiring any need of a 'Creator' or God. He cautions that:

> *"There is no intrinsic reason in the universe why it should exist at all, or why it should be what it actually is: hence we deceive ourselves if in our natural science we think we can establish that the universe could only be what it is."*

Let me now turn to a more serious problem with the "unique universe" argument, and one which is often glossed over. Even if the laws of physics where unique, it doesn't follow that the physical universe itself is unique, It seem, then, that the physical universe does not have to be the way it is: it could have been otherwise, 'Ultimately', it is the assumption that the universe is both contingent and intelligible that provides the motivation for empirical science. For without the contingency we would in principle be able to explain the universe using logical deduction alone, without ever observing it. And without the intelligibility there could be no science.

> *"It is combination of contingency and intelligibility,"*

writes the philosopher Ian Barbour,

> *"which prompts us to search for new and unexpected forms of rational order."*

Barbour points out that the contingency of the world is fourfold. First, the 'Laws of Nature' themselves appear to be contingent. Second, the cosmological initial conditions could have been otherwise. Third, we know from quantum mechanics that 'God plays dice' i.e., there is a fundamental statistical element in nature. Finally, there is the fact that the universe exists. This last point has been vividly expressed by Steven Hawking:

> *"Why does the universe go to all the bother of existing?"*

he asks.

> *"What is it that breathes fire into the equations and makes a universe for them to describe?"*

I believe that there is also a fifth type of contingency, which is to be found in the "higher-level" laws associated with the organisational properties of complex systems.

Let me first dispose of a rather trivial attempt at explanation that is sometimes proposed to avoid the need of a 'Divine Creator'. It has been argued by some that everything in the universe can be explained in terms of something else, and that in terms in something else again and so on, in an infinite chain. As I mentioned in my introduction this does not in fact answer the fundamental question about the origin of the universe, but rather puts off giving a answer. It is quite wrong to suppose that an infinite chain of explanation is satisfactory on the basis that every member of that chain is explained by the previous member .

G. W. Leibniz made this point eloquently by inviting us to consider an infinite collection of books, each one copied from a previous one. To say that the content of the book is there explained is absurd. We are still justified in asking who the author was.

It seems to me that, we have no choice but to seek that explanation in something beyond or outside the universe - in something metaphysical - because, as we have seen, a contingence or dependent physical universe cannot contain within itself and explanation for its self.

I believe it is natural to argue that the explanation lies in a creative agency which we call God. But what sort of nature does God have?

If it is excepted that the universe does not existed reasonlessly, and if we label the reason God, then the first question to tackle is: in what sense might God be said to be responsible for the ‘Laws of Nature’? There has to be some element of choice involved some possible universes would be discarded. By assumption, he would be rational. He should also be ‘Omnipotent.’ If God where not ‘Omnipotent’, then his power would be limited in some way. By similar reasoning, God would have to be perfect. He would also have to be ‘Omniscient’ - that is, he would need to be aware of all the logically possible alternatives - past, present and future.

Leibniz developed the above argument in detail to prove, on the basis of the rationality of the cosmos, that such a God exists. He concluded from this cosmological argument that a rational, omnipotent, perfect, omniscient being must exist.

Put simply, if the universe really has an explanation and it can’t explain itself, then it must be explained by something outside itself e.g. God. The age-old ‘who made God’ conundrum is in danger of pitching us into an infinite regress. To avoid this problem we have to assume that God can somehow ‘explain Himself’, which is to say that God is a ‘necessary being’ in the technical sense, that is to say he is completely independent and self-sufficient.. More precisely, if God is used to supply the explanation and reason for the existence of the universe, then it follows that he himself must be a ‘necessary being’, for, if God were contingent, then the chain of explanation would still not have terminated, and we would want to know what were the factors beyond God on which his existence and nature depended.

Many philosophers have argued that the idea of a ‘necessary being’ is incoherent or meaningless. Certainly human beings cannot comprehend the nature of such a being. But that does not mean that the notion of a necessary being is self-contradictory.

The idea of God as a ‘necessary’, timeless, immutable, perfect, omnipotent, omniscient being on which the universe depends utterly for its existence, but who in contrast is completely unaffected by the existence of the universe is the position held by Muslims from the time of the Prophet of Islam thirteen hundred years ago and traditional Christian theology from the time of Thomas Aquinas.

However, although the demands of rationality seem to compel us toward such a conclusion of God as the ultimate explanation of the universe, there has always been a serious difficulty about relating God to a contingent changing universe, with beings who posses free will, for Western philosophers, scientist and even Christian theologians are alike. This difficulty has lurked at the heart of Western theology ever since Plato.

The tension which this mismatch generates pervades science as surely as it pervades religion. The contribution of Christian thinking to this tension is the doctrine of creation *‘ex nihilo’*. Here was a brave attempt to break out of the paradox by proposing a timeless necessary being who brings into existence (not within time) a material universe by divine power as an act of free choice. By declaring that the creation is something other than the Creator, something which God strictures of the alternative scheme of divine emanation, wherein the physical universe issues directly from God’s essence and is thus imprinted with his ‘necessary’ properties. The key element that is introduced here is that of the divine Will.

By definition, free will entails contingency, because we say that a choice is free only if it could have been otherwise. So, if God is endowed with a freedom to choose between alternative possible worlds, the contingency of the actual world is explained. Yet the demand for intelligibility is preserved by attributing to God a rational nature, thereby ensuring a rational choice. This seems to be real progress. It appears as if creation *‘ex nihilo’* resolves the paradox of how a changing, contingent world can be explained by a timeless necessary being.

So far in this chapter I have been tracing the consequences of the ‘Cosmological Argument’ for the existence of God.

The history of theology is not, however, without attempts to prove that God's non-existence is logically impossible. This argument, known as the 'Ontological Argument'[27] and goes something like this: God is defined to be the greatest conceivable thing. Now, a really existing thing is obviously greater then the mere idea of that thing e.g. a real person like the famous Fabian of Scotland Yard is greater then a fictional character, such as Sherlock Holmes. Therefore, a really existing god is greater tan an imaginary god. But as God is the greatest conceivable thing, it follows that he must exist.

Even though the ontological argument reeks of logical trickery it has comparative philosophical thoughts. It has in fact been taken very seriously by many philosophers over the years, including Bertrand Russell. Nevertheless most Western theologians have not generally been prepared to defend it. One problem lies with the treatment of 'existence' as if it were a property of things, like mass or colour. Another objection against the ontological argument is the requirement that God supply the explanation of the universe.

The ontological argument however could only fail to prove the existence of God if the concept of a necessary being is incoherent. If the ontological argument is supported with another argument or arguments, then it could be successful. What of the 'cosmological argument'? If we accept the world's contingency, then the explanation is the existence of a transcendent God. We are not invoking God in the ancient, traditional sense of the 'god of the gaps' (The sun shines because God wants it to), but rather as a simplifying and unifying description of reality. The 'Laws of Nature' may be able to take us only so far, and we could then seek a deeper level of explanation and understanding.

The Philosopher Richard Swinburne, argued:

> *"It is easier to accept the existence of an infinite mind [God] than to accept, as brute fact, the existence of this contingent universe".*

Another theory which has been put forward to eliminate God from the discussion is the so-called many-universe theory. According to this theory which is currently popular with some physicists, there are an infinite number of universes with an infinite number of variations, so you could have a universe with an inverse cube law of gravitation. The question why this particular universe then becomes irrelevant as all possible universes co-exist anyway. However to postulate an infinity of unseen and unknowable universes just to explain the one we do see seems to be a case of excess baggage taken to the extreme. It is more elegant and simpler to postulate one Unseen God. Swinburne concludes:

> *"The postulation of God is the postulation of one entity of a simple kind...The postulation of the actual existence of an infinite number of worlds, between them exhausting all the logical possibilities... is to postulate complexity and non-prearranged coincidence of infinite dimensions beyond rational belief."*

Scientifically the many universe theory is unsatisfactory because it could never be falsified. You could use this theory to explain anything at all. Science becomes redundant. The regularities of nature would need no further explanation as they could just be explained as a selection effect of this particular universe. We will look at the many universe argument in the next chapter and I will demonstrate why it fails to give us the answers to our 'fundamental questions'.

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[27] Ontology is a branch of metaphysics dealing with the nature of being

Chapter Sixteen

The Infinite and Eternal

> *"But in the end a rational explanation for the world in the sense of a closed and complete system of logical truths is almost certainly impossible. We are barred from ultimate knowledge, from ultimate explanation, by the very rules of reasoning that prompt us to seek such an explanation in the first place. If we wish to progress beyond, we have to embrace a different concept of 'understanding' from that of rational explanation. possibly the mystical path is a way to such an understanding".* **Paul Davies**

In modern physical theory, rationality is reflected in the existence of fixed mathematical laws, and creativity is reflected in the fact that these laws are fundamentally statistical in form. The intrinsically statistical character of atomic events and the instability of many physical systems to minute fluctuations, ensures that the future remains open and undetermined by the present. This makes possible the emergence of new forms and systems, so that the universe is endowed with a sort of freedom to explore genuine novelty.

If there is a genuine stochasticity in nature, then the outcome of any particular "throw of the die" is genuinely undetermined by anything, which is to say that there is no reason why, in that particular case, that particular result was forthcoming.

So far in this philosophical excursion I have been largely concerned with logical reasoning. Little reference has been made to empirical facts about the universe. On their own, the ontological and cosmological arguments are a very good sign post for the existence of a 'necessary being' i.e. God. These arguments however when combined with the 'Design Argument' however, constitute a very powerful and I believe conclusive argument and proof for the existence of God.

Humans beings have always been awe struck by the subtlety, majesty, and intricate organisation of the physical world. The march of the heavenly bodies across the sky, the rhythms of the seasons, the pattern of a snowflake, the myriad of living creatures so well adapted to their environment-all these things seem too well arranged the elaborate order of the universe to the purposeful workings of a Deity.

The rise of science served to extend the range of nature's marvels so that today we have discovered order from the deepest recesses of the atom to the most distant galaxies. But science has also provided its own reasons for this order. No longer do we need theological explanations for snowflakes, or even for living organisms. The laws of nature are such that matter and energy can organise themselves into the complex forms and systems which surround us. Though it would be rash to claim that scientists understand everything about this self-organisation, there seems to be no fundamental reason why, given the laws of physics, all known physical systems cannot be satisfactorily explained as the product of ordinary physical process.

Some people conclude from this that science has robbed the universe of all mystery and purpose, and that the elaborate arrangement of the physical world is either a mindless accident or an inevitable consequence of mechanistic laws.

> *"The more the universe seems comprehensible, the more it also seems pointless,"*

believes physicist Steven Weinberg. The most biologist Jacques Monod echoes this dismal sentiment:

> *"The ancient covenant is in pieces: man at last knows that he is alone in the unfeeling immensity of the universe, out of which he has emerged only by chance. Neither has destiny nor his duty have been written."*

Not all scientists, however, draw the same conclusions from the facts. Though excepting that the organisation of nature can be explained by the laws if physics, together with suitable cosmic initial conditions, some scientists recognise that many of the complex structures and systems in the universe depend for their existence on the particular form of these laws and initial conditions. Furthermore, in some cases the existence of complexity In nature seems to be very finely balanced, so that even small changes in the form of the laws would apparently prevent this complexity from arising. A careful study suggests that the laws of the universe are remarkably felicitous for the emergence of richness and variety. In the case of living organisms, their existence seems to depend on a number of fortuitous coincidences that some scientists and philosophers have hailed as nothing short of astonishing.

There are several different aspects to this “too-good-to be-true” claim. The first of these concerns the general orderliness of the universe. There are endless ways in which the universe might have been totally chaotic. It might have had no laws at all, or merely incoherent jumble of laws that caused matter to behave in disorderly or unstable ways. Alternatively, the universe could have been extremely simple to the point of featurelessness - for example, devoid of matter, or of motion, One could also imagine a universe in which conditions changed from moment to moment in a complicated or random way, or even in which everything abruptly ceased to exist. There seems to be no logical obstacle to the idea of such unruly universes. But the real universe is not like this. It is highly ordered. There exist well defined laws of physics definite cause-effect relationships. There is a dependability always uniformly the same, to use David Hume’s phrase. This casual order doesn’t follow from logical necessity; it is a synthetic property of the world, and one for which we can rightly demand some sort of explanation.

The physical world does not merely display arbitrary regularities; it is ordered in a very special manner. As explained in chapter 5, the universe is poised interestingly between the twin extremes of simple regimented orderliness (like that of a crystal) and random complexity (as in a chaotic gas). The world is undeniably complex, but its complexity is of an organised variety. The states of the universe have “depth,” to use the technical term. This depth was not built into the universe as its origin. It has emerged from primeval chaos in a sequence of self-organising processes that have progressively enriched and diversified the evolving universe. This gradual self-organising according to what might be termed a cosmic blueprint is called the ‘Teleological Argument’. It is easy to imagine a world that, though ordered, nevertheless does not possess the right sort of forces or conditions for the emergence of significant depth.

There is another sense in which the order of the physical world is special. This concerns the general coherence and unity of nature, and the very fact that we can talk meaningfully about “the universe” at all as an all embracing concept. The world contains individual objects and systems, but they are structured such that, taken together, they form a unified and consistent whole. For example, the various forces of nature are not just a haphazard conjunction of disparate influences. They dovetail together in a mutually supportive way which bestows upon nature stability and harmony that are hard to capture mathematically but obvious to anyone who studies the world in depth.

It is particularly striking how processes that occur on a microscopic scale-say, in nuclear physics-seem to be fine tuned to produce interesting and varied effects on a much larger scale-for example, in astrophysics. Thus we find that the force of gravity combined with the thermodynamical and mechanical properties of hydrogen gas are such as to create large numbers of balls of gas. These balls are large enough to trigger nuclear reactions, but not so large as to collapse rapidly into black holes. In this way, stable stars are born. Many large stars die in spectacular fashion by exploding as so-called supernovae. Part of the explosive force derives from the action of one of nature’s most elusive subatomic particles-the neutrino.

Neutrinos are almost entirely devoid of physical properties: the average cosmic neutrino could penetrate many light years of solid lead. Yet these ghostly entities can still, under the extreme conditions near the centre of a dyeing massive star, pack enough punch to blast much of the stellar material into space. This detritus is richly laced with heavy elements of the sort from which planet Earth is made. We can thus attribute the existence of terrestrial like planets, with their Huge variety of material forms and systems, to the qualities of a subatomic particle that might never have been discovered, so feeble is its action. The life cycles of stars provide just one example of the ingenious and seemingly contrived way in which the large scale and small scale aspects of physics are closely intertwined to produce complex variety in nature.

In addition to this coherent interweaving of the various aspects of nature, there is the curious uniformity of nature. 'Laws of Nature' discovered in the laboratory apply equally well to the atoms of a distant galaxy. The electrons that make the image on your television screen have exactly the same mass, charge, and magnetic moment as those on the moon, or at the edge of the observable universe. Further more, these qualities persist with no detectable change from one moment to the next. The magnetic moment of the electron, for instance, can be measured with ten figure accuracy; even to such fantastic precision, no variation in its property has been found. There is also good evidence that the basic properties of matter cannot have varied much, even over the age of the universe.

As well as the uniformity of the 'Laws of Nature', there is also uniformity in the spatial organisation of the universe. On a large scale matter and energy are distributed extremely evenly, and the universe appears to be expanding at the same rate everywhere and in all directions. This means that an alien being in another galaxy would see very much the same sort of large scale arrangement of things that we do. We share with other galaxies a common cosmography and a common comic history.

Cosmologists have attempted to explain this uniformity using the so-called inflationary universe scenario, which involves a sudden jump in the size of the universe shortly after its birth. This would have the effect of smoothing out any initial irregularities. It is important to realise, however, that explains the uniformity in terms of a physical mechanism does nothing to lessen its specialness, for we can ask why the laws of nature are such as to permit that mechanism to work. The point at issue is not the way in which the very special form came about, but that the world is so structured that it has come about.

Finally, there is the much discussed simplicity of the laws. By this I mean that the laws can be expressed in terms of simple mathematical functions (like the inverse square law). Again, we can imagine worlds in which there are regularities but out of a very complicated sort requiring a clumsy combination of different mathematical factors. I believe that the "unreasonable effectiveness" of mathematics in describing the world is an indication that the regularities of nature are of a very special sort.

I have tried to make a case that the existence of an orderly, coherent universe containing stable, organise, complex structures requires laws and conditions of a very special kind. All the evidence suggests that this is not just any old universe, but one which is remarkably well adjusted to the existence of certain interesting and significant entitles (e.g., stables stars).

The situation becomes even more intriguing when we take into account the existence of living organisms. The fact that biological systems have very special requirements, and that these requirements are, happily, met by nature, has been commented upon at least since the seventeenth century. It is only in the twentieth century, however, with the development of biochemistry, genetics, and molecular biology, that the full picture has emerged. Already in 1913 the distinguished Harvard biochemist Lawrence Henderson wrote:

> *"The properties of matter and the course of cosmic evolution are now seen to be intimately related to the structure of the living being and to its activities;... the biologist may now rightly regard the Universe in its very essence as biocentric."*

Henderson was led to this surprising view from his work on the regulation of acidity and alkalinity in living organisms, and the way that such regulation depends crucially upon the rather special properties of certain chemical substances. He was also greatly impressed at how water, which has a number of anomalous properties, is incorporated into life at a basic level. Had these various substances not existed, or had the laws of physics been somewhat different so that the substances did not enjoy these special properties, the life (at least as we know it) would be impossible. Henderson regarded the “fitness of the environment” For life as too great to be accidental, and asked what manner of law is capable of explaining such a match.

In the 1960s the astronomer Fred Hoyle noted that the element carbon, whose peculiar chemical properties make it crucial to terrestrial life, is manufactured from helium inside large stars. It is released therefrom by supernovae explosions. While investigating the nuclear reactions that lead to the formation of carbon in the stellar cores, Hoyle was stuck by the fact that the key reaction proceeds only because of a lucky fluke. Carbon nuclei are made by a rather tricky process involving the simultaneous encounter of three high speed helium nuclei, which then stick together. Because of the rarity of triple nucleus encounters, the reaction can proceed at a significant rate only at certain well defined energies (termed “resonances”), where the reaction rate is substantially amplified by quantum effects. By good fortune, one of these resonances is positioned just about right to correspond to the sort of energies that helium nuclei have inside large stars. Curiously, Hoyle did not know this at the time, but he predicted that it must be so on the basis that carbon is an abundant element in nature. Experiment subsequently proved him right. A detailed study also revealed other “coincidences” without which carbon would not be both produced and preserved inside stars. Hoyle was so impressed by this “monstrous series of accidents”, he was prompted to comment that it was as if

> *“the laws of nuclear physics have been deliberately designed with regard to the consequences they produce inside the stars.”*

Later he was to expound the view that the universe looks like a “put up job” as though somebody had been “monkeying” with the laws of physics.

These examples are intended merely as a sample. A long list of additional “lucky accidents” and “coincidences” has been compiled since, most notably by the astrophysicists Brandon Carter, Bernard Carr, and Martin Rees. Taken together, they provide impressive evidence that life as we know it depends very sensitively on the form of the ‘Laws of Nature’, and on some seemingly fortuitous accidents in the actual values that nature has chosen for various particle masses, force strengths, and so on. As these examples have been thoroughly discussed elsewhere, I will not list them here. Suffice it to say that, if we could play God, and select values for these quantities at whim by twiddling a set of knobs, we would find that almost all knob settings would render the universe uninhabitable. In some cases it seems as if the different knobs have to be fine tuned to enormous precision if the universe is to be such that life will flourish. In their book Cosmic Coincidences John Gribbin and Martin Rees conclude:

> *“The conditions in our Universe really do seem to be uniquely suitable for life forms like ourselves”*

It is a truism that we can only observe a universe that is consistent with our own existence. As I have mentioned, this linkage between human observership and the laws and conditions of the universe has become known, somewhat unfortunately, as the Anthropic Principle. In the trivial form just stated, the Anthropic Principle does not assert that our existence somehow compels the laws of physics to have the form they do, nor need one conclude that the laws have been deliberately designed with people in mind. On the other hand, the fact that even slight changes to the way things are might render the universe unobservable is surely a fact of deep significance.

Has the Universe Been Designed by an Intelligent Creator?

The early Greek philosophers recognised that the order and harmony of the cosmos demanded explanation, but the idea that these qualities derive from a creator working to preconceived plan was well formulated only in the Christian era. In the thirteenth century, Aquinas offered the view that natural bodies act as if guided toward a definite goal or end "so as to obtain the best result." This fitting of means to ends implies, argued Aquinas, an intention. But, seeing as natural bodies lack consciousness, they cannot supply that intention themselves.

> *"Therefore some intelligent being exists by whom all natural things are directed to their end; and this being we call God."*

Aquinas' argument collapsed in the seventeenth century with the development of the science of mechanics. Newton's laws explain the motion of material bodies perfectly adequately in terms of inertia and forces without the need for divine supervision. Nor did this purely mechanistic account of the world have any place for teleology (final or goal directed causes). The explanation for the behaviour of objects is to be sought in proximate physical causes-i.e., forces impressed upon them locally by other bodies. Nevertheless, this shift of world view did not entirely put paid to the idea that the world must have been designed for a purpose. Newton himself, as we have seen, believe that the solar system appeared too contrived to have a risen solely from the action of line forces:

> *"This most beautiful system of the sun, planets and comets, could only proceed from the council and dominion of an intelligent and powerful Being."*

Thus, even within a mechanistic world view, one could still puzzle over the way in which material bodies have been arranged in the universe. For many scientists it was too much to suppose that the subtle and harmonious organisation of nature is the result of mere chance.

This point of view was articulated by Robert Boyle:

> *"The excellent contrivance of that great system of the world, and especially the curious fabric of the bodies of the animals and the uses of their sensories and other parts, have been made the great motives that in all ages and nations induced philosophers to acknowledge a Deity as the author of these admirable structures".*

The theologian William Paley argued:

> *"Suppose you were crossing a heath and came upon a watch lying on the ground. On inspecting the watch, you observed the intricate organisation of its parts and how they were arranged together in a co-operative way to achieve a collective end. Even if you have never seen a watch and had no idea of its function, you would still be lead to conclude from your inspection that this was a contrivance design for a purpose."*

Paley then went on to argue that, when we consider the much more elaborate contrivances of nature, we should reach the same conclusion even more forcefully.

Hume, argues however that this argument is week because it proceeds by analogy; the watch has a designer, so therefore the universe must have a designer. Clearly no analogical argument can amount to definite proof. The best it can do is to offer strong support for a theory. The degree of support depends on the persuasiveness of the analogy.

However as John Leslie points out, there are many scientists and philosophers who, even if the world were littered with pieces of rock stamped 'MADE BY GOD', who would still doubt the existence of God.

Individuals like Hume, Darwin and Richard Dawkins have played an important role in undermining the Design argument sufficiently to the point of it being more or less completely abandoned by western theologians. It is therefore very curious to see that it has been resurrected in recent times not by theologians but by scientists. In its new form the argument is directed not to the material objects of the universe as such, but to the underlying laws, where it is immune from Darwinian attack.

To see why let us go back to look at briefly the essential character of Darwinian evolution. At its heart, Darwin’s theory requires the existence of an ensemble, or collection of similar individuals, upon which selection may act. For example, consider the famous pepper coloured moth of industrial England. Imagine a collection of white coloured moths hiding from predators on the soot coloured walls of buildings. The predators easily see them and picks them off quickly. The moths have a hard time. Then by some genetic accident, a dark grey moth is hatched by one white moth. This grey moth makes a good living as it is well camouflaged from its predators on the soot covered walls. It lives longer and lives to pass on its advantageous traits on to its offspring. They too fare better, and produce still more grey moths. before long, the grey moths are dominating, taking all the food, and driving the white moths to extinction.

What is important to note in this example is that it is crucial for there to be many white moths in the beginning. One moth is then produced accidentally grey, and a selective advantage is gained over the others. The whole argument depends on nature being able to select from a collection of similar, competing individuals.

When it comes to the ‘Laws of Nature’ and the initial cosmological conditions, however, there is no ensemble of competitors. The laws and initial conditions are unique to our universe. Since it is the case that the existence of life requires the ‘Laws of Nature’ and the initial conditions of the universe to be precisely fine-tuned to an incredibly high level of precision as demonstrated in earlier chapters, and in fact then the suggestion of design seems very conclusive.

So far I hope the foregoing discussion will have convinced you that the universe is not just any old concoction of entities and forces, but a marvellous ingenious and unified system.

Consider the understanding of the origin of the universe as a jigsaw puzzle, with each piece of the puzzle being the underlying ‘Laws of Nature’. Each law being discovered and unravelled by scientific theory, experimentation and observation. These laws are then combined by newly discovered links, to unravel the workings of the universe. The links do not evolve, they are simply there. We must either accept these laws and links as truly amazing brute facts, or seek a deeper explanation.

I would like to summarise and conclude in this last chapter that this deeper explanation is that God has designed ‘Nature’ with considerable ingenuity and skill, and that the science of astrophysics, particle physics, quantum mechanics, chaos theory and biology are uncovering part of that design. The clear ‘fine-tuning’ of the ‘Laws of Nature’ and the initial conditions of the universe necessary for the for the existence of conscious life has clear implications that God has designed the universe so as to permit such life and consciousness to emerge. It would mean that our own existence in the universe formed a central part of God’s plan.

So do the ‘Cosmological Argument’, ‘Ontological Argument’ and the ‘Design Argument’ with reference in particular to the ‘Laws of Nature’ and the ‘Initial conditions of the universe’ combined with the Teleological Argument’ provide definite proof for the existence of a creator (God).

- The cosmological argument in essence states that the universe is limited or contingent and therefore dependant on something other than itself for its existence. We have proven that this something must itself be a ‘necessary’ being, self-sufficient and unlimited in it’s attributes i.e. infinite. We also concluded that it is impossible for us as limited beings to fully comprehend the infinite due to the paradox of self-referencing.

- The ontological argument states that God must exist as a consequence of logical necessity, because God is the greatest conceivable thing. A really existing thing is obviously greater then the mere idea of that thing e.g. a real thing like Apollo 13 the Space Craft, is greater than the Star Ship USS Enterprise of Star Trek fame (I hate to say for all you trekies out there). Therefore, a really existing god is greater than an imaginary god. But as God is the greatest conceivable thing, it follows that he must exist. The ontological argument however could only fail to prove the existence of God if the concept of a 'necessary' being is incoherent. But since we have proved the logical necessity for the existence of a 'necessary' being by virtue of the cosmological argument, it gives a very powerful argument for the existence of God.

- The design argument (abandoned by most Christian theologians, since the time of Darwin and Hume) also yield strong conclusive evidence for the existence of God when applied to the very "Laws of Nature' themselves and the initial conditions of the universe, that restrain the very processes of the workings of the universe. Here the process of Darwinian evolution fails to explain away the insurmountable '**Irrational odds,** need to be overcome to get the universe we observe today- Hence my title *Rational Universe, Irrational Odds.*

- And finally the Teleological Argument which states that the universe and what is in it is heading according to an ultimate plan or cosmic blueprint. This is proved by virtue of the fact that the universe has a definite tendency to organise itself. Instead of random chaotic distributions of matter in the universe we observe a definite ordering and structure, even though there is an underlying tendency of the universe naturally to disorder. Only an Omnipotent, omniscient and 'necessary' being is able to guide the universe according to this cosmic blueprint. Gods Cosmic Blueprint.

I believe that you the reader should now have ample evidence to decide the answers to our 'fundamental questions' of: 'Is there a God? And 'What is the origin of the universe?' I have tried to present the evidence in a coherent fashion but any mistakes are mine and in the evidence. I hope you come to the right conclusion. I believe that these evidences are conclusive and irrefutable in the proof of the existence of God. In the end 'You Must' decide.

In my next book I will demonstrate with greater detail how the belief in the existence of God does not in anyway mean an abandonment of scientific knowledge or lead to an understanding of a 'god of the gaps' but rather the two are very compatible. In particular the God of Islam as mentioned in the Holy Quran (the scriptures of the Muslim ideology), This understanding of God eliminates the contradictions and incoherencies found in Christian theology, between the existence of God and scientific knowledge. But more importantly the contradictions which are to do with understanding Gods attributes and the concept of Good and Evil, which traditionally remain outside the domain of science, but which have lead many Christian and Jewish theologians floundering against athiests in debate.