Thesis, Philosophy Honours, 2019

Prolegomena to scientific theology

Jeffrey Nicholls (a1757019)

Length: 18 000 words + 25% = 22 476 words
(Philosophy Handbook page 9)

Table of contents

Outline

* * *

* * *

* * *

Acknowledgements

The work presented here began in 1961 when I did Leaving Honours at Blackfriars school, taught by Anselm Curran and John Hooper. Both these priests had careers in industry before the joined the Order and gave us a solid grounding in science and mathematics.

Later I joined the same order, but my scientific education worked against me when I found that Philosophy and Theology in the Order were based entirely on the prescientific work of Aristotle and Thomas Aquinas. I felt that Aquinas' proofs that God is other than the world failed, and was inclined to agree with Aristotle's that the First Mover, from which Aquinas derived his God, is part of the Universe. This was (and remains) heretical in the Catholic Church, so I was asked to leave.

Now, fifty years later, I have taken up the issue again with the help of the Philosophy department at Adelaide University. I wish to thank all the professors who have tried to show me the ways of modern philosophy. I offer special thanks to Antony Eagle, who has tried to guide me toward producing an acceptable argument for the identity of God and the Universe.

Preface

This thesis is an attempt to carry speculative theology beyond the apogee it reached in the medieval work of Thomas Aquinas into the world of empirical science (Aquinas 2019). Since the time of Aquinas, our understanding of the Universe has increased enormously. The ancient theologians not only conceived a perfect God, but they also saw the world as a very imperfect place. Their reaction was to place God outside the world.

I will argue that we live in a Universe which approaches infinity in size and complexity, is as perfect as can be, and fulfils all the roles traditionally attributed to God, creator, lawmaker and judge. By being able to add our knowledge of the universe to the thousands of years of wisdom accumulated by philosophers and theologians, we are in a position to lead theology into the realm of natural science. Here the information available to explore divine nature vastly exceeds all past exploration of the nature of divinity.

* * *

In the Pastoral Constitution *Gaudium et Spes* the Roman Catholic Church makes an extraordinary series of claims about the future of humanity:

> We do not know the time for the consummation of the Earth and of humanity, nor do we know how all things will be transformed. As deformed by sin, the shape of this world will pass away; but we are taught that God is preparing a new dwelling place and a new earth where justice will abide, and whose blessedness will answer and surpass all the longings for peace which spring up in the human heart. Then, with death overcome, the sons of God will be raised up in Christ, and what was sown in weakness and corruption will be invested with incorruptibility. Enduring with charity and its fruits, all that creation which God made on man's account will be unchained from the bondage of vanity (Pope Paul VI, 1965, ¶39)

These words spring from a culture whose people thought that we and the Earth lay at the centre of the Universe, and that “The World was created for the glory of God” (Catholic Catechism ¶293).

Now we know that the Sun is one of the hundreds of billions of stars in one of the hundreds of billions of galaxies that populate the Universe. There is really no reason to think that there should not be other intelligent species in the Universe. The problem is that even if there are billions of species like us, the nearest is likely to be millions of light years distant, making it impossible to communicate with them.

* * *

Theology is the traditional theory of everything. In each culture theology or its equivalent serves as the frame of reference that gives meaning to human existence. Sharing a common theology binds communities together. Theologies also have powerful political significance, even in communities that claim to be secular.

Western theological tradition derives its God and the first version of its theology from the Hebrew Bible, known in Christian circles as the Old Testament. We cannot deny that many features of the civilization we now enjoy owe much to Christianity, but it has very significant limits.

In particular, the story of creation in *Genesis* paints us as sinful beings, infected with *original sin* because the first people listened to Satan and ate the forbidden fruit of the tree of life (Catholic Catechism ¶¶ 385-421). This story is the *raison d'etre* of Christianity, which holds that the murder of Jesus of Nazareth, God become human, appeased God for the original sin and made possible the salvation of humanity alluded to by the Vatican Council above.

Christianity spread through the Mediterranean world and, in the time of Constantine, became the established religion of the Roman Empire. From that time it has grown to be a global force.

* * *

The scientific approach to knowledge began to gain momentum in the time of Galileo. Galileo built a telescope and saw without doubt that the planets revolve around the Sun. The inquisitors understood this to contradict the passage in the book of Joshua where we read *the sun stood still in the midst of heaven and hasted not to go down about a whole day* (10:13, KJV). Despite his high status and friendship with the Pope, the Inquisition gave him a choice: recant or die. Wisely Galileo recanted.

Galileo lost, but since his time the scientific consensus has become very powerful and has transformed almost every feature of human existence.

Religion and theology have lagged behind however, due to institutional inertia. The root of the Christian position is the claim that God is invisible and mysterious, out of the reach of science, revealed to us only through Jesus and the traditional scriptures and prophets.

Science is based on observation, not ancient authority. If theology is to be a science, God must become visible. This requires the identification of God and the Universe. The purpose of this thesis is to take a step in that direction by arguing that it is reasonable to conceive the observable Universe as divine.

Introduction

The Plot

Aristotle and Aquinas had beautiful minds but they were children of ages when people knew almost nothing about how the world works. In a nutshell, they totally misunderstood the nature of matter, and it was not until the advent of quantum mechanics that we realised that it is exceedingly complex and interesting.

Arisotle's model of potency and act led him all the way from physics to metaphysics, but his dynamic axiom, *a potency can only be actualized by something already actual* was found to be in error when the discoverers of energy conservation realised that energy comes in two guises, potential and kinetic.

Aristotle did not notice that a frictionless pendulum will convert potential energy to kinetic energy and back again forever because they are precisely equivalent. Potential corresponds to static structure, kinesis corresponds to dynamic motion, and the two are manifestations of the same underlying reality, action. Heracleitus and Parmenides were both touching the same elephant.

The only tool we have powerful enough to elucidate the nature of matter is logic. The Catholic theologian Bernard Lonergan opened my eyes to this when he tried to produce a psychological transformation of Aristotle and Aquinas' proof for the existence of God. His attempt failed, as we shall see, but the idea was there.

Aquinas relied particularly on six of Aristotle's tools in his *Summa*, *matter, form, agent*, and *end*, the four causes, and *potency* and *act*, two dynamic principles. In this thesis I propose to replace these tools with *computation* and *communication* to produce a theological model which encompasses the logical power of the mathematics that grew out of the pioneering work of Whitehead and Russell (Whitehead & Russell 1910).

Four chapters and a conclusion

The starting point for this thesis is the first part of the *Summa Theologiae* of Thomas Aquinas. In this part he deals with God, creation and divine control of the world.

The first elaboration of Christian doctrine was derived principally from Platonic philosophy. Aquinas rebuilt Christian Theology on an Aristotelian basis. His work enjoys special authority in the Catholic Church (John Paul II, 1983, Canon 252: §3)

In chapter I point out some of the difficulties apparent in traditional theology seen from a modern point of view. First, modern physics weakens Aquinas' first proof for the existence of God by rejecting the Aristotelian notion that no potential can actualize itself without the intervention of an actual being. Second, a supreme being of absolute simplicity, despite its claimed omniscience and omnipotence, does not have the power to create the enormously complex universe we inhabit. This conclusion is derived from the cybernetic principle of requisite variety that Chaitin finds implicit in Gödel's incompleteness theorem. This principle demonstrates that simple system like the classical God cannot specify a complex system like the universe. Then, inspired by a failed attempt by Bernard Lonergan to modernise Aquinas' theology, I outline a communication network model of the universe, beginning with human communication. This model is based on the theory of information developed by the telecommunication industry and the theory of computation developed Turing. In this thesis the network model serves as a replacement for the Aristotelian model of God applied by Aquinas.

Chapter 2 begins with the Hawking and Ellis study Einstein's general theory of relativity which suggests that the universe began as a structureless initial singularity. This point is formally identical to the traditional God described in the previous chapter. This chapter then follows the evolutionary complexification of the universe via the "big bang" to its present state. Beginning with simple structures like fundamental particles, we see them bond by communicating with one another to form more complex structures. Evolutionary history, extending over about 14 billion years, united fundamental particles to form, in temporal sequences, atoms, stars, galaxies, planets, molecules, living cells, multicellular creatures, societies and ecosystems. All the steps toward our current state still exist in one form or another, available for scientific study. The evolutionary history that has led to humanity shows that all the features of humanity are natural outcomes of evolution. The universe as we know it does not demand the special creation of a spiritual soul at the moment of conception to explain the fact that we are intelligent beings created in the image of God.

Chapter 3 adds substance to the network model suggested in chapter 1 by applying it to some of the evolved structures in the universe described in chapter 2. I begin with the medieval scholastic theory of the Christian Trinity. Next I describe the foundations of communication in the universe in terms of the quantum of action. Then I use five real networks to illustrate some of the features of the abstract network model: the internet; general relativity; a quantum network; the human brain, a neural network which is the organ of mind; and finally the global network of scientists. These discussions of the properties of particular networks serve as a foundation for the argument in the next chapter that it is reasonable to understand the universe as the divine mind. I then suggest that the deterministic structure of this framework reaches the limits of consistent computation and completeness and goes beyond this bound into the uncertainty predicted by Gödel's incompleteness and Turing’s incomputability. This uncertainty serves as the foundation for the random variation that is necessary for the evolutionary paradigm to work. Natural selection chooses from these variations those that are sufficiently consistent and deterministic to work, that is to survive and reproduce. More generally, the variation and selection in the cosmic network underlies the creative process in the universal system.

Chapter 4 completes the argument by showing that the network model, as implemented in the observable universe, shares some of the attributes the classical God. The Christian God is understood as the infinite, omniscient and omnipotent creator and controller of the world. It is also understood as the supreme value, the apotheosis of human existence, (*Genesis*, 1:1, *ST*, I II, 1, 4).

The first part of the chapter claims that the three quoted attributes of God apply to the Universe revealed by science. The network model enables us to conceive of the Universe as filling the logical space of consistency. This reflects Aquinas's definition of God, pure act, the realisation of all possibility. Outside this space is inconsistency, that is nothing.

The second part of the chapter deals with the relationship between God as understood in this thesis and ourselves, individuals of the species *Homo sapiens.*

Aquinas, following Christian doctrine, holds that God created the world to share its goodness with humanity. This occurs in two stages: The first is the *Incarnation*. It is believed that God became human in the person of Jesus of Nazareth, granting us some vision of divinity (*ST* III, 1, 1). The second is the vision of God enjoyed by the blessed in the next life (*ST* I II, 3, 8). Implicit in this doctrine is that the goodness of God is the ultimate human value.

In the picture presented here each of us is divine insofar as we are subsystems of the divine Universe. It follows that all our experience is experience of God. In reality, however, this experience is not all bliss. The states of divine perfection imagined by Christian theologians cannot be consistently realized. Instead we must deal with the complex environment in which we find ourselves. I conclude this thesis with the observation that if the world is itself divine we can expect no help from an outside God and must take responsibility for our own welfare.

Chapter 1: A divine world?

Outline

* * *

1.0 Abstract: problems and answers

In this chapter I point out some of the difficulties apparent in traditional theology from a modern point of view. First, modern physics weakens Aquinas' first proof for the existence of God by rejecting the Aristotelian notion that no potential can actualize itself without the intervention of an actual being. Second, a supreme being of absolute simplicity, despite its claimed omniscience and omnipotence, does not have the power to create the enormously complex universe we inhabit. This conclusion is derived from the cybernetic principle of requisite variety that Chaitin finds implicit in Gödel's incompleteness theorem. This principle demonstrates that a simple system like the classical God cannot specify a complex system like the universe. Then, inspired by a failed attempt by Bernard Lonergan to modernise Aquinas' theology, I outline a communication network model of the universe, beginning with human communication. This model is based on the theory of information developed by the telecommunication industry and the theory of computation developed Turing. In this thesis the network model serves as a replacement for the Aristotelian model of God applied by Aquinas.

1.1 Does God exist?

A primary question for every science is the existence of its subject. So Aquinas asks *Does God exist*? (Aquinas, *ST* I, 2, 3).

This leads to the question *what is God*? In the Christian tradition this question is answered in the first verse of *Genesis: In the beginning God created the heavens and the earth* (Genesis I:1). God is the creator.

This definition effectively renders Aquinas question superfluous. If the heavens and the earth were made by God, and they obviously exist, the creator must exist too.

Nevertheless, Aquinas provides five ways to argue for the existence of God. These arguments do not so much prove that God exists as they prove that God is other than the world. The first way, which I will discuss in a moment, is taken directly from Aristotle. Before I go any further, however, I must point out the role Aristotle plays in the work of Aquinas.

1.2 The Aristotelian world of Thomas Aquinas

Traditional Western theology is principally a product of the Christian Churches. My plan is to replace the model of God developed by Thomas Aquinas in the thirteenth century using the work of Aristotle, with a model based on communication and computation, with a view to developing a scientific hypothesis which identifies the traditional conception of God with the Universe as we know it.

The source of Christianity, the Bible, has very little to say about the nature of God. Almost all we have on this subject is the work of Greek Philosophers beginning in the time of Parmenides and culminating in the work of Aristotle. This ultimately became the foundation of medieval Scholastic philosophy and theology.

Aristotle begins with the idea that there must be an eternal immutable substance, as proposed by Plato. This form alone is not sufficient to cause motion however, so he proposes that the essence of this substance must be actuality (*Metaphysics* 1071b20). After discussing more details of this motion he concludes:

> Such, then, is the first principle upon which depend the sensible universe and the world of nature. And its life is like the best which we temporarily enjoy. It must be in that state always (which for us is impossible), since its actuality is also pleasure. . . . .. If, then, the happiness which God always enjoys is as great as that which we enjoy sometimes, it is marvellous; and if it is greater, this is still more marvellous. Nevertheless it is so. Moreover, life belongs to God. For the actuality of thought is life, and God is that actuality; and the essential actuality of God is life most good and eternal. We hold, then, that God is a living being, eternal, most good; and therefore life and a continuous eternal existence belong to God; for that is what God is. (*Metaphysics* Book XII, 1072b14 sqq.)

Aquinas built his theology in the world described by Aristotle. By modern standards, Aristotle's physical world was tiny. He had one dynamical principle, the theory of potency and act, and knew very little about how things worked beyond the attribution of four causes, matter, form, agent and end.

His mental world was much bigger, comparable to ours. His work is still alive in modern philosophy. He began with treatises on logic and the interpretation of texts. He then went on to speculate about space and time, the heavens, life and death, ethics, rhetoric, politics.

Christian speculative theology reached its most complete expression in the *Summa Theologiae* of Thomas Aquinas, written between 1265 and 1274. Aquinas remains a core theologian in the modern Catholic Church. His presentation of God in the first part of the *Summa* is the starting point for this work. His principal contribution was to introduce Aristotelian philosophy to Catholic theology to produce a synthesis which remains official in the Catholic Church (Code of Canon Law: Canon 252 §3).

Much of Aquinas' theological argument is built on the six Aristotelian ideas listed above: matter, form, agent, end, potency and act.

1.3 God is not the world: the *first way*

Aquinas offers five proofs for the existence of God (*ST* I, 3). The first, *et manifestior* is taken from motion and explains both the relationship of *potentia* to *actus* and concludes with a definition of God: *actus purus*, pure action:

> It is certain, and evident to our senses, that in the world some things are in motion. Now whatever is in motion is put in motion by another, . . . For motion is nothing else than the reduction of something from potentiality to actuality. But nothing can be reduced from potentiality to actuality, except by something in a state of actuality. . . . Therefore, whatever is in motion must be put in motion by another. . . . Therefore it is necessary to arrive at a first mover, put in motion by no other; and this everyone understands to be God (*ST* I, 2, 3).

Aristotle believed that the unmoved mover is part of the cosmos. Aquinas, true to his faith, concludes that God is other than the world.

1.4 Pure act implies absolute simplicity

Having established the existence of a God, Aquinas goes on to discuss its nature. Here he notes an ancient opinion, which became a fundamental principle of traditional theology, that God is so far beyond our comprehension that we are completely unable to understand it. We cannot, therefore, say what God is, but only what it is not, denying to God inappropriate properties such as composition and motion. This *via negativa,* or *apophatic theology* owes its origin to Pseudo-Dionysius the Areopagite (Corrigan & Harrington).

A principal consequence of the hypothesis defended here is that God is visible to us so that theology may join the mainstream of empirical science. Moving in the opposite direction, Aquinas reinforces the difference between God and the universe by arguing that God is absolutely simple (*omnino simplex*).

God is not a body, that is not spatially extended (*ST* I, 3, 1); does not comprises matter and form (2) (Ainsworth 2016); is identical with its essence or nature: *Deus est ipsa deitas* (3); essence and existence (*esse*) are identical in God (4); God is not an element of any genus (5); there are no accidents (*accidentia*) in God (6).

Having exhausted these Aristotelian categories of composition he concludes that God is absolutely simple (7), and finally that God in no way enters into composition with other things (8).

Aquinas then goes on to derive all the other traditional attributes of God from pure actuality. These include perfection (*ST 1,* 4), goodness (6), infinity (7), omnipresence (8), immutability (9), eternity (10), unity (11), knowledge (12), power (25) and beatitude (26).

1.5 Two difficulties: potency and act, and complexity

The key to Aquinas' first proof is Aristotle's axiom: *no potential being can actualize itself.* Modern physics rejects this axiom..Potential motion is just as real as actual motion, as we see in the motion of a pendulum. At the top of its swing, the bob has gravitational potential energy. As it swings down, this potential is converted to kinetic energy. On the upward swing the opposite happens, and in a frictionless world, this cycle of transformation from potential to kinetic energy and back would continue forever.

The world is in effect its own first mover. I will discuss below how quantum mechanics explains that energy is everywhere and is accompanied by ceaseless motion. As a result, Aquinas' first argument that God is other than the world fails.

The second problem concerns the relationship between the simplicity of the divine creator and the complexity of the created world.

Of principal interest here is the knowledge of God. Is there knowledge in God? Yes, says Aquinas, arguing from Aristotle's doctrine of matter and form:

> In God there exists the most perfect knowledge. To prove this, we must note that intelligent beings are distinguished from non-intelligent beings in that the latter possess only their own form; whereas the intelligent being is naturally adapted to have also the form of some other thing; for the idea of the thing known is in the knower. Hence it is manifest that the nature of a non-intelligent being is more contracted and limited; whereas the

> nature of intelligent beings has a greater amplitude and extension; therefore the Philosopher says (*De Anima* iii:8, 431b20) that "the soul is in a sense all things." Now the contraction of the form comes from the matter. Hence, . . . forms according as they are the more immaterial, approach more nearly to a kind of infinity. Therefore it is clear that the immateriality of a thing is the reason why it is cognitive; and according to the mode of immateriality is the mode of knowledge. Hence it is said in *De Anima* ii that plants do not know, because they are wholly material. But sense is cognitive because it can receive images free from matter, and the intellect is still further cognitive, because it is more separated from matter and unmixed, as said in *De Anima* iii. Since therefore God is in the highest degree of immateriality . . . it follows that He occupies the highest place in knowledge (*ST* I, 14, 1).

From a modern point of view, this discussion completely misses the point since it is a general metaphysical argument which does not touch on the mechanism of knowledge. In a way, Aristotle comes close when he defines the soul as *the first actuality of natural body possessed of organs* (*De Anima* 412b5).

We understand that knowledge is a form of information, and we now understand that all information is represented by a physical marks of some sort, as we can see on the everyday macroscopic scale in all forms of sensory stimuli, visible, audible and tangible. In a nutshell, information is a physical entity (Landauer 1996).

Aristotle was not to know that the organs of a living body are constructed on a microscopic molecular scale that only became visible with the advent of electron microscopes which can resolve molecules. Indeed he structure of the world continues well beyond the reach of electron microscopes into the atomic nucleus whose scale is typically millions of times smaller than any molecule. Every element of this structure my serve as a representative vehicle, so that the Universe has vast information carrying capacity..

The cybernetic principle of *requisite variety* tells us that a complex system can only be controlled by a system of equal or greater entropy or complexity (Ashby 1964). Gregory Chaitin has shown that this principle is a consequence of Gödel's incompleteness theorem (Chaitin 1982):

> Gödel's theorem may be demonstrated using arguments having an information-theoretic flavour. In such an approach it is possible to argue that if a theorem contains more information than a given set of axioms, then it is impossible for the theorem to be derived from the axioms. In contrast with the traditional proof based on the paradox of the liar, this new viewpoint suggests that the incompleteness phenomenon discovered by Gödel is natural and widespread rather than pathological and unusual.

Traditional theology maintains that the combination of the divine omniscience and omnipotence gives God the ability to completely know and control every detail of the future. Requisite variety invalidates this claim. Insofar as God is understood to be absolutely simple, its variety is zero, and so its powers of knowledge and control are absent.

1.6 Bernard Lonergan: another failed proof of God

The Catholic theologian Bernard Lonergan set out to modernise Aquinas' work (Lonergan 1992). His argument for for the existence of God follows the same track as Thomas:

> . . . the five ways in which Aquinas proves the existence of God are so many particular cases of the general statement that the *proportionate universe* is incompletely intelligible and that complete intelligibility is demanded (p 678).
>
> The proportionate universe contains proportionate being. Proportionate being may be defined as whatever is known by human experience, intelligent grasp, reasonable affirmation (p 391).

Lonergan claims that the proportionate universe is incompletely intelligible because it contains *empirical residue*. The empirical residue . . . consists of positive empirical data, . . . is to be denied any immanent intelligibility of its own . . . . (pp 25-26)

Lonergan approaches the empirical residue through

> inverse insight: . . . while direct insight meets the spontaneous effort of intelligence to understand, inverse insight responds to a more subtle and critical attitude that distinguishes different degrees or levels or kinds of intelligibility. While direct insight grasps the point, or see the solution, or comes to know the reason, inverse insight apprehends that in some fashion the point is that there is no point . . . the conceptual formulation of an inverse insight affirms empirical elements only to deny an expected intelligibility. (p 19)

I feel that Lonergan' s empirical residue is model dependent: it does not correspond to anything in reality. Lonergan' s misunderstanding is at least as old as Parmenides: he mistakes an abstraction for reality. In an abstract way it is true, as Lonergan says ... *that (1) particular places and particular times differ as a matter of fact, and (2) there is no immanent intelligibility to be grasped by direct insight into that fact.*

The physical models which we use to summarise the relationships of events in the universe are formal constructs which were never meant to imply that there is no intelligibility in the relationships of real events such as the impact of a particular hammer on a particular nail at a particular time in the construction of a particular house. Einstein' s general theory of relativity does not require the existence of space and time independent of events.

1.7 Conversation: Sharing meaning, the human network

Lonergan approaches God through human understanding. He begins from Archimedes' *eureka*: lying in the bath he understood the hydrostatic law that the upthrust on a floating body is equal to the mass of liquid displaced.

Language and communication have long been central issues in philosophy, and one of the central issues for any speaker is to find forms of words that lead listeners to understand the idea they want to convey.

The unit of communication is a conversation which may be the exchange of a single symbol between two people (*yes; no*) or a long drawn out process like a course of study.

Historically philosophical conversations about conversation have proceeded without any knowledge of the mental processes we use to encode and decode the contents of our minds to and from strings of phonemes. Psychology, neurophysiology, cognitive science, semantics and other relevant sciences are slowly elucidating these questions, but we need know nothing about these subjects to talk to one another. This all became habitual when we learnt to speak. We are natural communicators, which means that a theology expressed in terms of communication may be.intuitively easy to understand.

One function of human networks is to embody argument, the exposition and testing of hypotheses expressed in words. One task of argument is to detect and reject inconsistency. This philosophical process serves as a paradigm for the creative evolutionary powers of networks to be described below. The basic idea is that large scale networks of conversation explore the space of possibility, and in the process discover new possibilities and exclude impossibilities.

Evolution by natural selection is an example of such network behaviour.

1.8 Causality, communication and computation

Mathematics has played a central role in science since earliest times and in many civilizations (Joseph 2010). Galileo's mathematics did not go far beyond Euclidean geometry, arithmetic and simple algebra. Since his time mathematics has expanded enormously.

The discovery of differential and integral calculus by Newton and Leibniz opened the way for Newton's the study of motion for Riemann's development of the differential geometry which is the mathematical foundation of general relativity.

Calculus reopened questions of infinity and continuity which had first been raised by Zeno. The search for a logically consistent exposition of calculus lead to mathematical analysis and the theory of real numbers with sufficient cardinality to be placed into correspondence with the points of the real line.

Georg Cantor set out to find a representation of the cardinal of the reals and discovered set theory and the transfinite numbers (Cantor 1890, 1897, 1955). He realized that ordinal numbers could be used to represent any formal structure, opening mathematics to the study of language and logic and to the development of the function spaces which became important in the theories of computation, information and quantum mechanics. Cantor's work motivated Whitehead and Russell to seek to express all of mathematics in terms of logic (Whitehead & Russell 1910, 1962).

The logical language they developed for this purpose helped Gödel develop his completeness and incompleteness theorems, which led to Chaitin's treatment of the cybernetic principe of requisite variety mentioned above. (Feferman *et. al.* 1986). Their work also laid the foundation for the Turing's mechanization of logic to create the first universal computer (Turing 1936).

Turing formalized the idea of a definite procedure. An explanation based on a definite mechanical procedure is rational, ie it makes sense. Here I hope to exploit the idea of a computer network to provide a rational mechanical explanation of divinity. An important idea is that rational network mechanism is not necessarily deterministic, and so allows for randomness and creation.

Communication is a form of remote control. As you read this, ideas in your mind are to some extent being shaped by ideas that originated in my mind and led to the composition of this text. The coupling here may be quite loose since there is plenty of room for misunderstanding, but when we come to matters of law and military command, words and messages become both easy to understand due to established conventions and explicitly causal.

The intelligibility of the universe depends upon the casual relationships between its parts and we may assume that the stability of the universe depends upon the precision and accuracy of the communication of information between the elements from which it is constructed.

The need for error free communication is universal. Fundamental particles must communicate without error to form stable atoms just as the members of a human community must communicate without error to form stable communities. The problem of error arises in an engineering context in human telecommunication systems. It was solved by Claude Shannon's mathematical theory of communication (Shannon 1949, Kinchin 1957).

The implementation of Shannon's theory is made possible by computation. Shannon achieved error free transmission by coding the information into blocks which, as they grow bigger, can be made so far apart in the signal space that the probability of confusion can be reduced without limit. This has the consequence that all error free transmission of information must be digital, as we find in nature.

Computation is necessary to encode messages for transmission and to decode the messages so transmitted. This system is very efficient. It has made structures like the internet possible, enabling the transmission of gigabytes of information error free over noisy channels.

Here we can see the emergence of a virtuous circle, since computation is itself a communication process. Elements of a computer must transmit messages to one another to execute a computation. We can thus imagine a large scale computer using smaller computers to guarantee the integrity of its internal communications, and so the integrity of its overall computation. We see this structure in the universe. We may interpret atoms as small.machines which guarantee the integrity of molecular machines. These contribute in turn to the integrity of cellular machines which contribute to the integrity of multicellular machines like ourselves. This construction process is built into the history of evolution.

In antiquity Plato's forms and Aristotle's intellect were understood to be 'separate' that is form without matter.

The problem with separate forms is that they are no longer qualify as representative vehicles. Landauer has explained that information is a physical entity and the mathematical theory of communication requires orthogonal physical symbols to enable error free communication. From this point of view, a true continuum can not represent information. We need marks, so that in contrast to Aristotle's view, we need the exceedingly fine grained structure of the material universe to represent information (Shannon 1949).

Many believe that the universe is inherently continuous and so best described by continuous mathematics. Shannon showed, however, that quantization is required for error free communication. The simplest form quantization is the binary code used in binary digital computer and communication networks. Logic and arithmetic meet at the binary level. Computers are constructed with networks of Boolean operators. Arithmetic numerals are constructed with strings of binary digits. Cantor discovered that anything “thinkable” could be represented with suitably encoded ordered set (Cantor 1955, page 117, Ross & Wright 1992).

The union of computers and communication provides us with a means to model the world which can replace the Aristotelian ideas used by Aquinas. This approach and takes advantage of our natural affinity with communication to make the world easier to understand.

1.9 Some properties of networks

Formally a network is a set of communication links. A communication link comprises two sources that are able to send and receive messages, and a channel between them that can carry information. Networks are ubiquitous and thus a promising structure to be developed as a theory of everything, that is a theology. They have many useful properties:

1.9.1 Networks create real relationships

We create and maintain our human relationships by communicating with one another. It seems that all other relationships, bonds and structures in the universe are built on networked communication.

1.9.2 Computer networks are *logically continuous*

We may understand a halting Turing machine as a logically continuous mechanism. Given a certain initial state, it will move by a series of deterministic steps to a final state which is a logical consequence of the initial state. It executes a *proof.* Modern digital computers and a error free digital communication channels are also logically continuous in the same sense. The output of an error free transmission channel will be identical to its input, so it may be considered as a machine that does nothing other than copy information from one point in space-time to another.

1.9.3 Networks may be made redundant and fail safe

The road network of a country or city normally provides many distinct routes to get from *A* to *B*. If one route is blocked, another is most likely to be available. This property may be built into any network, so that a route may be found between any two sources, at least until the network is so badly damaged that it is divided into disconnected sections.

1.9.4 Networks can be logically mapped

A problem facing any network user is to decide which is the best route to take between two points. The usual way to do this is to consult a map of the network. Networks like the internet have machines devoted to routing, and the packets comprising a long message may take different routes from point to point. Engineered networks operate like a postal system. Each packet of information carries a destination address which the routing machinery uses to send it on in the right direction.

1.9.5 Networks embody both certainty and uncertainty

Networks, like the internet, can be designed to be deterministic, but uncertainty can enter in three ways. The first is error, although error detection and correction is possible in a well designed network. The second is by lossy encoding, where some loss of detail is acceptable in order to reduce the size and cost of transmission. The third is by the interruption and redirection of a processes by interaction with other processes. Our lives, for instance, are regularly redirected by out meetings with other people and events.

The effect of this uncertainty it to introduce randomness into a system enabling it explore the whole probability space of possible connections. This situation lays the foundation for an evolutionary process. Many potential connections will lead to inconsistency and failure..Others will establish stable connections. In the Darwinian model, stable relationships are the ones selected for survival.

1.9.7 The future is uncertain but past is fixed

There may be many different routes through a network and the actual course of processing may depend on random events like the exact moment at which a machine receives a message to interrupt and redirect its process. In retrospect, however, the actual path taken is determinate, and in the case of the whole universe, can (in principle) be traced back to the initial singularity. This suggests that

Lonergan's *empirical residue* is mistaken, since every event has a pedigree stretching back to the beginning

1.9.8 Networks.increase complexity by copying

The function of communication network is to copy information one from point to another in spacetime, and this increases the overall complexity of the system. This tendency is opposed by erasure. In biological networks the death and decay of individuals release resources for use by other organisms.

1.9.9 Networks explore the space of possibility

Evolving biological, cultural. technological and scientific networks explore inevitably exploit new possibilities, laying the foundation for evolution by natural selection. We often see paradigms changes resulting from developments in network technology like printing, and telephones.

1.9.10 They are scale invariant

Fundamental particles, atoms, molecules, people, stars and and galaxies are all instances of communication sources. The network paradigm applies regardless of the size of the communicating entities.

1.9.11 They reflect the layered structure of the universe

Networks are layered, beginning with the physical network. Each layer uses the services provided by the layer beneath it to serve the layer above it. We see a similar structure reflected in the world. Fundamental particles communicate with one another to form the networks we call atoms. Atoms network to form molecules, molecules cells, cells multicellular creatures, such creatures network to form ecologies and so on. Each of these layers can exist without the layers above it, but relies completely on the layers beneath it.

1.9.12 They may be multiplexed in time and space

Sources which are closely bound like electrons and nuclei may be in regular communication with one another, but most acts of communication are discrete entities with an finite lifetime..Much of the technology in computer networks like the internet is devoted to making and breaking connections.

1.9.13 Coding and decoding: language and meaning

The mathematical theory of communication is not concerned with the meaning of messages, but with accurate transmission.

The embodiment of meaning in messages is the work of the users (sources) in the network. In the case of the internet, the users are predominantly human. although machines (‘things’) can also use it. As in face to face communication, the meanings of messages are introduced by the users encoded in a language common to them both.

Like the traditional God the initial singularity, taken by itself, means nothing. Formally, meaning is established by correspondence, as in a dictionary. Physically it is established by bonding which is a relationship established by communication.

Atoms, although infinitesimal, are already quite complex structures. Each new layer of structure in the universe adds new layer of meaning which is encoded in the syntax of the structure. This relationship between layers is universal, so I may consider myself as an element of the human layer on Earth, relying on many ecosystem and economic layers for my survival and contributing to all the networks within which I am a source.

This structure establishes that the meaning of my life can be traced back to the initial singularity, and my life contributes to the meaning of all the systems of which I am part.

1.9.14 Networks enable testing and selection

The creation of anything, even a written sentence, requires trial and error. Evolution and the history of technology demonstrates this beyond doubt, since no species or technological product has ever emerged in its final form. Design is an evolutionary process of copying with variation. On the whole the variations are random. They cannot be predicted, but just happen and must be found. New designs are tested and selected when they begin to communicate with their environment.

1.9.15 There is no logical upper bound to networks

From a logical point of view, there is no limit to the size of networks. Nevertheless, communications are limited by the velocity at which messages can travel. In physical Universe as a whole this is limited by the velocity of light, so that even if there are human civilizations on other planets, given the size of the universe communications with them may take hundreds, thousands or millions of years if they are possible at all.

1.10 The cosmic network

I have introduced the network model as a modern equivalent of the Aristotle’s matter, form, agent, end, potency and act to describe processes in the world. I suggest that a network paradigm is a promising candidate for a description of the universe as a whole.

Chapter 2: The evolution of the Universe

* * *

2.0 Abstract:

This chapter begins with the Hawking and Ellis study Einstein’s general theory of relativity which suggests that the universe began

as a structureless initial singularity. This point is formally identical to the traditional God described in the previous chapter. This chapter then follows the evolutionary complexification of the universe via the "big bang" to its present state. Evolutionary history, extending over about 14 billion years, united fundamental particles to form, in temporal sequences, atoms, stars, galaxies, planets, molecules, living cells, multicellular creatures, societies and ecosystems. All the steps toward our current state still exist in one form or another, available for scientific study. The evolutionary history that has led to humanity shows that all the features of humanity are a natural outcome of evolution..The universe as we know it does not demand the special divine creation of a spiritual soul at the moment of conception to explain the fact that we are intelligent beings created in the image of God.

2.1 From Aristotle's *De Caelo* to Einstein's General Relativity

> In scientific investigations it is permitted to invent any hypothesis, and if it explains various large and independent classes of facts it rises to the rank of a well-grounded

theory. . . . The principle of natural selection may be looked at as a mere hypothesis, but rendered in some degree probable by what we positively know of the variability of organic beings in a state of nature,—by what we positively know of the struggle for existence, and the consequent almost inevitable preservation of favourable variations,—and from the analogical formation of domestic races. Now this hypothesis may be tested,—and this seems to me the only fair and legitimate manner of considering the whole question,—by trying whether it explains several large and independent classes of facts; such as the geological succession of organic beings, their distribution in past and present times, and their mutual affinities and homologies. If the principle of natural selection does explain these and other large bodies of facts, it ought to be received. On the ordinary view of each species having been independently created, we gain no scientific explanation of any one of these facts. We can only say that it has so pleased the Creator to command that the past and present inhabitants of the world should appear in a certain order and in certain areas; that He has impressed on them the most extraordinary resemblances, and has classed them in groups subordinate to

> groups. But by such statements we gain no new knowledge; we do not connect together facts and laws; we explain nothing (Darwin 1875).

Aristotle and his contemporaries believed the heavenly motions to be perfect circles. This assumption made it difficult to explain the wandering motions of the planets and was not resolved until Kepler found that the orbit of Mars is an ellipse with the Sun at one focus (Kepler 1517, 1621, 1995).

Kepler's results helped Isaac Newton to lay the foundations of classical mechanics and to develop his theory of universal gravitation. Newton's work explained the structure of the Solar System but has nothing to say about electromagnetic phenomena and relied on the difficult assumption of instantaneous gravitational action at a distance (Newton 1729, 1972).

Einstein revised classical mechanics in two steps, his special and general theories of relativity. Special relativity is founded on the assumption that the maximum speed of causal influences in the Universe is the speed of light *c,* an electromagnetic phenomenon.

The special theory introduces the two leading ideas of modern physics, *symmetry* and *transformation.*

Special relativity holds in *inertial frames* in which Newton's first law of motion holds: *a body at rest remains at rest and a body in motion continues to move in a straight line unless acted upon by a force.* An observer moving inertially is weightless, ie feels no force.

A symmetry is something that stays the same independent of motion. The symmetry of special relativity is that all observers in inertial motion, regardless of their relative speeds, see the same laws of physics, in particular the same velocity of light. This symmetry implies the *Lorentz transformation* (Misner, Thorne & Wheeler, 1973). The Lorentz transformation ensures that the every observer in an inertial frame sees the same speed of light, regardless of the speed of its source.

Special relativity describes a force free world. The dominant force in our lives is the gravity which holds us onto our spherical planet. Aristotle explained that the natural motion of heavy objects is down. Einstein explained this motion by introducing a new symmetry and a new transformation which defines the large scale structure of the Universe (Pais 1982, pp 111-291).

The new symmetry is the invariance of space-time distance between events regardless of an observer's state of motion. The new transformation is Einstein's *field equation*. Newton understood space and time as fixed independent frames of reference in which massive bodies moved under the influence of force (Newton 1713, 1726).

In Einstein's theory, space and time are no longer a passive background. The geometry of space-time is itself the explanation of gravitation, an approach called *geometrodynamics* (Misner, Thorne & Wheeler 1973). Objects in inertial motion, that is in free fall, nevertheless accelerate toward one another, as we see in the motion of a satellite around Earth. We standing Earth feel gravitation because our free fall is prevented by the Earth, whose strength is the result of a non-gravitational interaction, electromagnetism.

Aquinas, following long tradition, argued that God is absolutely simple (*ST*, 3). Hawking and Ellis, studying Einstein's general theory of relativity, concluded that it points to an initial point in the existence of the universe which shares the two principal properties of the classical god: it is completely without structure, that is absolutely simple, and it is the source (creator) of the universe:

> Einstein's General Theory of Relativity . . . leads to two remarkable predictions about the universe: first that the final fate of massive stars is to collapse behind an event horizon to form a 'black hole' which will contain a singularity; and secondly that there is a singularity in our past which constitutes, in some sense, a beginning to our universe (Hawking & Ellis 1975).

The existence of the theoretically predicted initial singularity is supported by astronomical observation..This singularity precedes space and time. We can no more ask where it came from that we can ask where God came from. Insofar as there is are no grounds for distinguishing these two entities, it seems reasonable to identify them.

2.2 Creation: the emergence of complexity in simple

dynamics

How did the structureless initial singularity become the current universe? On the cosmic scale, the beginning of this process has come to be called the “big bang”. We do know what made the big bang “go off” but we can observe and study the result, which includes ourselves (Peacock 1999, Weinberg 2008).

At the microscopic scale physics, electron microscopy and molecular chemistry have elucidated the detailed structure matter.

Each of our own bodies is a precisely detailed arrangement of some 10^{24} atoms, each of which has a countable infinity of internal states. Our complete physiological system performs some 10^{50} operations (quanta of action) per second so, in a hundred year lifetime of about 3 billion seconds, a person completes some 10^{60} operations, an unimaginably large number which serves to indicate the complexity of life and the minuscule scale upon which life is constructed. The Universe occupies a space-time almost infinitely larger than a single person..We wish to see how all these operations fit together to create a huge dynamic system.

2.3 Energy and mass

In Section 2.1 I introduced the special relativistic version of inertial space. One consequence of this structure is the relationship $M = E/c^2$, between mass *M,* and energy *E* and the speed of light *c*. High energy physics experiments show that sufficient energy can create massive particles. The big bang is to understood not only to create space-time, but to populate it with large numbers and many varieties of fundamental particles.

These particles fall into two groups: *bosons* and *fermions*. Bosons, like the *photon*, are communication particles. Fermions, like *electrons*, are source particles. While many bosons may exist in the same physical state, each state can be occupied by one fermion only, which is understood to give spatial structure to composite particles in the Universe. An atom, for instance, has a certain size because its electrons must all occupy spatially discrete states.

There are four species of boson, corresponding to the four known forces. All known particles communicate through gravitation. Electrically charged particles communicate through *photons*. Gravitons and photons are massless and have potentially infinite range. The bosons of the strong force are known as *gluons*. The bosons of the weak force are the electrically charged W^+ and W^- and the neutral *Z*. The range of these massive bosons is comparable to the size of the atomic nucleus, about 10^{-15} metre.

There are two general classes of fermions known as *leptons* and *quarks*. All these particles and their interactions are described by the *standard model*. (Particle Data Group). Through their interactions fundamental particles can bind together to form structures of all sizes from *protons* (complex fermions) to galaxies.

2.4 Quantum mechanics: cosmic harmony

The *standard model* is an application of quantum mechanics which serves, like classical mechanics, as a toolkit for describing causal interactions. Quantum mechanics identifies energy with frequency and implements a harmonic paradigm. Overall, the microscopic elements of the universe interact only if they are in tune with one another. White light shines through glass, for instance because nothing in the glass resonates with the photons in the light, and so there is no interaction. Other substances are opaque and coloured because electrons within them are able to resonate with light. Quantum network interactions are explained in more detail in chapter 3 (Feynman 1988, Zee 2003).

2.5 Building the Universe: galaxies and stars

Fundamental particles constitute the microscopic structure of the universe. The are considered to be infinitesimal or to have no size at all. The scale of activity at this level of the universe is set by the quantum of action which, from the human point of view, is exceedingly small, measured by Planck's constant, 6.6×10^{-34} *Joule.second*.

The large scale structure of the universe is often measured in light years, the distance light travels in a year at 300 000 kilometres per second. A year is about 30 million seconds, so light year is approximately 10 trillion kilometres. The radius of the visible part of the universe is roughly equivalent to it age, about 14 billion light years. The curvature of space-time means that it has no boundaries other than the initial singularity and the singularities in black holes. These numbers show that the Universe is not only very big, but that its structure is also very detailed.

Gravitation, as described by the general theory, explains the large scale structure of the Universe, its overall expansion, and the local contraction of masses of material to form galaxies and stars. The original big bang created the nuclei of hydrogen and helium. After about 400 000 years the system had cooled enough for electrons and nuclei to bind together to form neutral atoms. Since atoms do not scatter light as much as isolated charged particles, photons were then able to travel large distances. Most of our knowledge of the early universe comes from observing the *cosmic microwave.background radiation* which dates from this epoch. (NASA 2012).

Large self gravitating volumes of gas formed galaxies, and smaller and denser regions of galaxies began to contract and heat up by compression eventually reaching high enough temperatures to become stars and initiate the nuclear interactions which create heavier elements. Sufficiently large stars eventually used all their nuclear fuel and collapsed to become black holes, neutron stars or supernovas, creating heavier elements and distributing them through space to form the next generation of stars and their planets.

2.6 Planets

Under suitable conditions, masses of dust surrounding stars condensed to become planets. The inner planets of our Solar System mainly comprise heavier elements in the form of rock. The outer planets of comprise lighter elements and molecules. The Earth occupies the “goldilocks zone” around the Sun which allows the existence of liquid water, and has a magnetic field which protects it to some extent from ionizing radiation. Many other chemical and structural conditions also existed which enabled the origin of life, particularly the relatively benign and plentiful solar radiation reaching Earth and the existence of the gaseous atmosphere.

2.7 Biological evolution

The solar system formed about five billion years ago and life on Earth dates from about three billion years ago. *Genesis* attributes the creation of life on Earth to God’s *fiat,* and it was long held that all the species of contemporary life on Earth remained precisely as they were created. People in close contact with nature would have been aware that this is not so, but it was not until the time of

Charles Darwin that these changes became of scientific interest (Darwin 1859, 1998, 2009).

2.7.1 Energy

The evolution of life requires energy. Although some forms of life may have evolved using chemical energy, most life depends on solar energy. This energy has a thermodynamic temperature of about 6000 K, so its is low entropy compared to the 300 K surface temperature of Earth and the 3 K temperature of space. Solar energy drives chemistry on the surface of Earth away from equilibrium making the complex structures of life far more probable than they would be in an equilibrium situation (Prigogine 1980, Kauffman 1995).

2.7.2 Reproduction

The foundation of continued life in the face of death is reproduction, the ability of systems to copy themselves. At the quantum level, the creation of particles like atoms and molecules may have been a random process, although the particles we know have widely different lifetimes and so are subject to a form of selection..At a more complex stage molecules (*replicators*) may have emerged that are capable of catalyzing the production of copies of themselves (Wilkins 2018).

Among living creatures, reproduction may be sexual or asexual. Asexual reproduction divides the parent and creates two or more daughters. Sexual reproduction does not necessarily involve immediate annihilation of the parents, although in some species the egg laying partner may eat the source of sperm to increase its fitness. Although parents inevitably die in the long run, they may live long enough to feed and educate their young.

Reproduction overcomes death, which is a consequence of the gradual accumulation of errors in a complex organisms. Living creatures control error by keeping two copies of themselves. The living organism nourishes and protects itself, suffers wear and tear in the course of life, and eventually dies. It contains a *genome,* which is a representation of the organism encoded in molecules of *nucleic acid, RNA* and *DNA.* The genome is highly compressed representation of the whole creature, so its mass is generally only about 1% of its owner. It is well protected from the environment and surrounded by error correction and copying mechanisms which minimise its rate of error and duplicate it for reproduction. On reproduction new relatively perfect organisms are created using the information in genome.

2.7.3 Variation

There is, nevertheless, a certain rate of error in the processes of life and reproduction so an asexual organism may not reproduce identical copies of itself. Viruses have no genetic error control, and so mutate rapidly. Sexual reproduction introduces variation by randomly mixing the genomes of the parents..It also provides an opportunity for error detection and correction by enabling comparison of two copies of each gene. The variations introduced by error and the blending of the genes of two parents in sexual organisms may enable faster evolution. The immune systems of multicellular organisms have specially designed variable elements in their genome to cope with the wide variety of the pathogens and parasites in the environment (Chaplin 2010).

2.7.4 Selection

Selection presupposes a criterion, which is in effect the environment into which a creature is born. Natural selection "chooses" to breed from the progeny which are capable of producing fertile offspring. Multicellular creatures use spectrum of reproductive strategies running from the production of many offspring of which few survive to those, like mammals, which nurture a limited number of offspring to adulthood. Other simpler species may have large numbers of offspring which are left to take their chances..A species will survive if and only if it maintains its population.

The modular nature of living systems opens the way for detailed selection operating, for instance, on visual acuity, speed, strength, and features which play a role in sexual selection. We have good evidence in increasing cranial capacity that our ancestors been strongly selected for improved cognitive abilities (Klein 2009).

2.7.5 Death and recycling

Life is physical, so the exponential growth of living organisms would soon exhaust the physical materials.life if they did not die and release matter for recycling. All living things are sources of energy, and therefore food for other organisms. One of the principal marks of fitness is the ability to avoid being eaten before reproducing.

2.7.6 Competition *versus* cooperation

Darwin draws attention to the “struggle for life” in the title of *The Origin of Species* which emphasises the competitive element of survival, but life itself is a cooperative activity. Each living cell may be viewed as a molecular cooperative activity reminiscent of Adam Smith’s description of an economy based on the interaction of workers specialised in different tasks (Smith 1776, 1994).

This cooperative structure builds up from simple to more complex organisms. The first living creatures appear to have been single cells, but over time many varieties of such cells evolved the ability to bind together by communicating with one another to form a multicellular structure with cells themselves differentiating and specializing for such tasks as sensation, motion and information processing. As we see in human social groupings, individuals best able to cooperate and form corporate associations are likely to improve their chances in the competition for resources for survival.

2.8 Cultural evolution

The evolutionary paradigm can work at all scales of space and time. The Darwinian cycle of genetic evolution, reproduction with variation and selection, works very slowly, each cycle taking a generation. A generation may be about an hour in simple unicellular creatures, stretching to a century in long lived animals and many centuries in some plants.

The emergence of mobile animals with senses, a nervous system with memory and muscles began with the *Cambrian explosion* about 540 million years ago and laid the foundation for the more rapid adaptation of individuals to their environment by cultural transmission of learned information from one generation to the next.

Species in which parents nurture their young enable the offspring to learn by observing their parents and being taught by them. From an evolutionary point of view, memory formed by experience increases the probability of survival and reproduction.

Cultural evolution moves the site of adaptation from information stored in genes to information stored in the nervous systems of individuals and shared through space and time by communication between individuals. The prevalence of such *cultural evolution* is observed to become more common as we move up the tree of life and has played a critical role in enabling *Homo sapiens* to dominate the Earth. In the last few centuries the mass schooling of children in the 3 R's greatly increased the rate and scope of cultural evolution. Printing, jet travel, and now the the internet now gives an individual.access to all the cultures of the world and the resulting cross fertilization can be expected to create a Cambrian explosion of culture.

2.8.1 Language

Communication between individual creatures dates from earliest times. Bacteria communicate by sharing molecules sometimes called *pheromones*, a property which remains with us in our sense of smell and which is developed to a very high level of precision in many species. Bacteria may also share genes and other complex molecules.

In addition to molecular communication visual and physical contact and sound emerges in mammals and becomes more elaborate as we move up the phylogenetic tree. One of the most important development leading to human supremacy is the evolution of syntactical communication. The power of language enables detailed planning and execution of complex cooperative activities (Nowak, Plotkin and Jansen, 2000).

2.8.2 Technology and art

Technology is the modification of the environment by living creatures to improve their chances of survival. We see it at every level of the tree of life from bacteria encasing themselves in protective film, to the complex structures built by termites, bees and other insects, to ourselves. Technology depends on communication and cooperation and is a form of cultural evolution.

Like other forms of evolution, it depends upon creative variation, trial and selection by success or failure. Successful technologies are propagated, failures die, but may provide clues which lead to ultimate success. Modern technologies may evolve quickly. Hand held networked computers.are barely ten years old but have changed the pattern and content of human telecommunication.

2.8.3 Scientific method

The foundation of technology is knowledge of the properties of our physical environment. The conscious systematic and cooperative search for such knowledge is *scientific method.* From an abstract point of view (to be explored in more detail in the next chapter) we may see the whole evolutionary process beginning with the big bang as an unconscious implementation of technology based upon information obtained by unconscious but effective scientific method. Each new step in the construction of the universe depends upon knowledge and exploitation of the step before it. The formation of stars and planets is a consequence of the interactions of gravitation and quantum mechanics and we can follow the chain of such interactions up the tree of life to ourselves.

The role of science is the precise elucidation of the mechanisms that make particular elements of the universe work as they do. The "genes" of science are the elements ("articles") of the scientific literature, shared by the scientific community and used by individuals in particular disciplines as a foundation for further variation and selection to add further detail to our cultural representations of our environment. Science itself evolves using the same mechanisms as the evolution of the Universe, "muddling through", expecting the unexpected..(Fortun & Bernstein, 1998).

2.8.4 Heyes' gadgets: universal machinery, mills and grist

Turing devised a universal computing machine which depends on the fact that the only difference between program and data is in syntactic arrangements determined by the semantic structure in the minds software engineers. The only difference between the software and data is its role. Data is in effect the fundamental symmetry of the logical universe.

Heyes applies the same approach to the cultural evolution of mind. She distinguishes between mills, that is software systems, and grist, data to be processed..Human minds are mills which have evolved a "starter kit" of milling processes, social tolerance, attentional biases and a universal processor, the brain. These, she claims, have been expanded and adapted to deal with the enormous complexity of modern social life and explain the vast difference between chimpanzees and humans which seem rather mysterious when we consider the small genetic differences between the two species (Heyes, 2018 pp 52 *sqq*).

2.9 Are we immortal?

A strong attraction of the Christian religions is the notion that death is not real. The Second Vatican Council refers to this belief in the document quoted in the Preface to this thesis. The foundation of this belief is the resurrection of Jesus of Nazareth recorded in the New Testament (Matthew 28:1-10).

Aristotle provides some philosophical foundation for this belief in *De Anima:*

> Mind in the passive sense is such because it becomes all things, but mind has another aspect in that it makes all things; this is a kind of positive state like light; for in a sense light makes potential into actual colours. Mind in this sense is separable, impassive and unmixed, since it is essentially an activity (*De Anima* III, iv: 430a14-18, Shields 2016)

Aquinas follows Aristotle in arguing that the human soul must be immaterial, subsistent, incorruptible and therefore immortal (*ST*, I, 75, 2).

There appears to be be no modern evidence for immortality. As I explain in the next chapter, the network structure of the human central nervous system provides sufficient reason for intelligence without the need to invoke separation.

Chapter 3: The universe modelled as a network

* * *

3.0 Abstract

This chapter adds substance to the network model suggested in chapter 1 by applying it to some of the evolved structures in the universe described in chapter 2. I begin with the medieval scholastic theory of the Christian Trinity. Next I describe the foundations of communication in the universe in terms of the quantum of action. Then I use five real networks to illustrate some of the features of the abstract network model: the internet; general relativity; a quantum network; the human brain, a

neural network which is the organ of mind; and finally the global network of people. These discussions of the properties of particular networks serve as a foundation for the argument in the next chapter that it is reasonable to understand the universe as the divine mind. I then suggest that the deterministic structure of this framework reaches the limits of consistent computation and completeness and goes beyond this bound into the uncertainty predicted by Gödel's incompleteness and Turing’s incomputability. This uncertainty serves as the foundation for the random variation that is necessary for the evolutionary paradigm to work. Natural selection chooses from these variations those that are sufficiently consistent and deterministic to work, that is to survive and reproduce. More generally, the variation and selection in the cosmic network underlies the creative process of the universal mind.

3.1 The network atom

The notion of a network serves here as the foundation of a model of everything. The atom of a network comprises two *sources* and a communication *channel* linking them. Source means any system capable of transmitting and receiving information. Such atoms may be assembled to create a universe of communication, each source communicating with other sources like the users of a telephone network.

The atoms themselves are scale invariant, comprising any system from a fundamental particle to a human being or a galaxy. Networks establish logical coupling between their elements. They create by copying and they introduce uncertainty through the random interruption of one process by another. The network atom models is a real relationship which is based on communication and serves to bind sources together, even if only temporarily. Networked communications are the backbone of the universe, binding all its elements together into a coherent whole. Sections 1.9.1-15.above list come properties of networks.

3.2 The Christian Trinity

The doctrine of the Trinity introduced a radical new idea into theology. The writers of the New Testament, while maintaining the Hebrew tradition of monotheism, added a new and rather mysterious feature to God, the Trinity, that is three distinct persons, Father, Son and Spirit.

The Trinity provides a framework for the history of salvation. The Father is the Creator; the Son a divine envoy to Earth, sacrificed to placate the angry Father insulted by human sin; and the Spirit a guide to steer recalcitrant humanity toward its eternal heavenly destiny.

This literary fiction posed a conundrum for theologians. The problem is clearly illustrated by the icon known as *scutum Trinitatis,* a diagram which illustrates the claim that the Father, the Son and the Spirit are identically God, yet the Father is not the Son, the Son is not the Spirit and the Spirit is not the Father (Shield of the Trinity). This structure appears self contradictory.

One approach is to accept that it is a mystery beyond understanding. The other is to seek an explanatory mechanism. Augustine first took on this task (Augustine 1991). He was followed 800 years later by Aquinas (*Summa,* I, 27, 1 *sqq*). Aquinas follows the classical theological axiom that since God is *omnino* *simplex* features which are distinct in created beings are identical in God.

The first verse in the John's Gospel, *In the beginning was the Word,* provides a clue to modelling the Trinity. This sentence refers to the inner mental word that precedes the utterance of a verbal word in everyday speech (Lonergan 1997, 2007, 2009). Since God's word is identical with itself, the word of God *is* God, but *proceeds* from the Father, establishing the relationships of *paternitas* and *filiatio* which establish the orthogonality of Father and Son. As with the word, these relationships (Aquinas *relatio*) are identical to God. The Son is a real image of the Father, distinguished from it by real relationships.

The procession of the Son is thus understood as an act of intellect. Following scholastic psychology, the procession of the Spirit is seen to be an act of will. The Spirit is the substantial love between the Father and the Son.

The analogous problem for this project is the existence of independent particles in the universe. The answer is provided by space, which enables the simultaneous and consistent existence of *p* and *not-p*. For each *p* there may be an infinity of *not-p*s, distinguished by different locations in space-time.

We may see the Trinity as an ancient expression of what is here called a network atom. Father and Son are sources. The Spirit is the channel between them.

Aquinas points out the the distinctions between the persons of the Trinity are realised by relationships that are real in God, and as with all the other attributes of God, identical with the divine nature. In the network picture of the world, relationships established by communication have an analogous ontological role, their reality lies in the exchange of physical information. They bind particles together to give them structure and meaning while respecting their separation.

3.3 Binding the network to the world

Aristotle and Aquinas saw God as pure action. Here we identify God and the Universe and understand that the Universe itself is pure action. The coupling between the abstract network, based on the theories of communication and computation, and the real world, is the quantum of action, *h,* the measure of the fundamental physical act of communication in the Universe. Abstractly, an action converts some *p* into some *not-p.* From an information theoretical point of view, the distance between *p* and *not-p* is one *bit,* often represented by a *bi*nary digi*t,* eg 0 or 1. This establishes a relationship between the physical quantum of action and the logical measure of contradiction and information.

Quantum mechanics began in 1900 when Max Planck discovered that events in the universe are pixellated in quanta of action (Planck 1901). An event is an act of communication between two particles, in Planck's case between a photon and an atom. There is no observable action smaller than a quantum of action, but quanta of action fit together by networking to produce larger actions like human lives and supernovae

As with pixellated photographic images, details smaller than a pixel are unresolved, and consequently uncertain. In physics the pixellation due to the quantization of action appears in three different ways. The physical dimension of the quantum of action is angular momentum so it is naturally related to *spin* which in turn is closely related to the harmonic paradigm of quantum theory (2.4). One way to imagine a wave is as a point on a moving wheel.

The quantum of action also appears in the two forms of the uncertainty principle which limit the resolution of of energy with respect to time and momentum with respect to space: $\Delta E.\Delta t \cong h$ *and* $\Delta p.\Delta x \cong h$, where h is Planck's constant, E energy, t *time,* p momentum and x distance (Feynman, Leighton & Sands, 1971).

3.3.1 Logical and physical measure

Corresponding to this abstract logical model of an event outlined above are physiological and physical changes that describe the same in a more concrete way. The logical network model proposed in this chapter is intended to establish abstract but useful models of the physical events that serve as modern version of Aristotle's ideas of cause, potency and act.

3.3.2 Source entropy and information

The mathematical theory of communication defines a *source A* by the alphabet a_i of symbols that it can transmit and receive. The present text, as a source, uses the alphabet of a computer keyboard. In information theory, uncertainty is measured by *entropy* a count of possibilities. The power of a source is measured by its *source entropy, H,* the average entropy per symbol. Information removes uncertainty, so the measure of information is numerically identical to the measure of the uncertainty removed.

Once a transmitting source emits a particular symbol, the receiving source is no longer uncertain about which symbol it will emit next and receives information equivalent to the source entropy. The entropy (per symbol) of a source is computed from the probabilities p_i of the letters a_i using the formula $H = -\Sigma_i p_i \log_2 p_i$ where H is the source entropy measured in bits per symbol. The rate of information transmission on a communication link is the product of the source entropy by the rate of emission and reception of symbols (Shannon 1949, Khinchin 1957).

3.3.3 Communication, quantization and error prevention

Physical systems are subject to noise (ie irrelevant messages) which can corrupt messages and processes. Errors occur when symbols are confused due to their being too close together in signal space and ‘smudged’ by noise. As I have noted, the basic strategy of error correction is to assemble symbols into large packets which are so far apart in message space that the probability of confusion is minimised and any damage to a packet is detectable so that the receiver can request retransmission.

Quantization surprised nineteenth century physicists steeped in the ancient tradition of a continuous world, yet it is ubiquitous. We are all individuals, surrounded by individual trees, flowers and blades of grass. Although we are inclined to think of these things as static objects, in a dynamic Universe they are better conceived as operations. From this point of view my life is one long complex action or event comprising a huge number of quanta of action, that is the atomic events counted in 2.2 above.

3.3.4 A message is an observable physical entity

Aristotle and Aquinas viewed information and systems that carried information as ‘separate’ or immaterial entities. Modern cognitive science, on the other hand, imagines that information is carried by physical “representative vehicles”. There is nothing to be learnt from a blank sheet of paper until it is decorated with marks made of physical ink. A perfect continuum carries no information. The information carrying capacity of the Universe is realized by marks or actions, whose size is measured by the quantum of action, which is exceedingly small.

The reasoning in Turing’s paper on computtion must be implemented in the mind of a reader for the force of his argument to become apparent (Turing 1936). The machine that Turing had in mind was a human computer working with pencil and paper.
A key idea for the development of mechanical computers is that both logic and arithmetic can be encoded in binary numerals and binary digits can be represented by any two state mechanical or

electrical system. Further, as Cantor noted, any structure can be represented by a syntactically ordered set of discrete elements (Cantor 1955 p 117).

3.4 Real networks

3.4.1 The internet

David Hilbert was a mathematical optimist. He felt that no mathematical problem would go forever unanswered. On 8 September 1930, he told the Society of German Scientists and Physicians:

> We must not believe those, who today, with philosophical bearing and deliberative tone, prophesy the fall of culture and accept the *ignorabimus*. For us there is no *ignorabimus*, and in my opinion none whatever in natural science. In opposition to the foolish *ignorabimus* our slogan shall be: *Wir müssen wissen – wir werden wissen*. ('We must know - we will know.') (James T. Smith)

He was to be disappointed. Gödel showed that consistent mathematics is incomplete and Turing devised a formal machine that could reasonably be claimed to be able to compute anything computable and used it to show that there are problems that his machine cannot solve (Feferman 1986, Turing 1936, Davis 1982).

The *Turing machine* serves as a definition of ‘computable’. From a practical point of view, a computer is the physical embodiment of an algorithm or set of algorithms. There are a countable infinity of different algorithms. A machine which can be programmed to execute any of these algorithms is called a universal Turing machine (Hopcroft, Motwani & Ullman 2001)

Any algorithm except the simplest can be constructed by a sequence of lesser algorithms (like the individual arithmetic operations in multiplication). Turing demonstrates this in his paper, using the term *abbreviated tables* for what we now call *subroutines*: self contained procedures which can be given a problem by a process and return an answer to that process. In a living organic body seen as a network, for instance, we may imagine the body calling a muscle cell which returns a certain motion.

Modern computers implement Whitehead and Russell's idea that logic embraces the whole of computable (and communicable) mathematics, since in a binary digital computer all algorithms are ultimately broken down to a sequence of propositional functions. Further, all these operations can be modelled with a single operation known to logicians as the Sheffer Stroke and to computer people as the NAND gate (Mendelson 1987).

Modern computers are controlled by a clock. When the machine is in a certain static (formal) state, a clock pulse initiates the physical operations necessary to bring the machine to it next state. The next clock pulse cannot be issued until all the physical components of the machine have settled into a new static state. The regimentation imposed by the clock has the effect of hiding the physical dynamic transitions so that the logical behaviour of the machine is guided by the sequence of static states, rendering it behaviour deterministic.

The formal difference between a computer and a computer network lies in the timing and the sharing of memory. Both may be considered as the set $\{P, M\}$ of logical processors P which read from and write to memory M. A simple computer is, *synchronous,* driven by one clock and usually has a memory space available for its exclusive use.

A network of computer mays be *asynchronous.* Individual processors on the network have their own clocks. There are billions of computers on the internet, all running at their own speeds, and there are network protocols to take care of these differences. In addition, network computers share memory, so when my computer connected the internet I can send a URL (*universal resource locator*) which the network machinery will use to find the memory storing the information I want and send it back to me.
Each computer on the internet is an autonomous machine which has a life of its own, like a cell in a body. The rate of internal communication within the computer itself far outweighs the rate which it communicates with other machines through the network. The universal network has a similar structure. Autonomous units like atoms and stars maintain their integrity by rapid internal

communications which are far more frequent than the messages they send and receive to and from their peers.

The internet now reaches about one third of the world's human population. It thus serves as a familiar paradigm, from a user's point of view, of the nature and capabilities of computer networks. The internet is also self documenting, so that anyone who wishes to understand the details of its structure and operation can search and find this information stored in the network (Tanenbaum 1996).

The heart of the internet is a global space of shared memory which can be accessed by all the machines in the network. Every point in this space has an address. This addressing system, like all computer memory, is arranged hierarchically. At the top level we have domains, like *https://www.adelaide.edu.au/.* Within the domain we have a tree of addresses which eventually narrows down to a specific file: /../../*file*. Within the file every character has an address, and every address contains a sequence of bits which are the ultimate destinations of the addressing system, to be transmitted one by one by the machine requesting the file.

The universe by analogy, assigns a space-time address to every quantum of action in the universal process. Every event has meaning based on its place in the universal memory and the history which brought it to its current state (1.9.7). We understand the structure of the universe as the space of its constituent events

3.4.2 Gravitation

Einstein's general theory of relativity explains gravitation and the large scale structure of the Universe. It is based on the differentiable manifold, a mathematical construct invented by Bernhard Riemann. This manifold is a flexible and elastic form of space created by joining many infinitesimal Euclidean spaces together.

The structure is complex but a rough approximation can be visualised by considering chain mail made of small rigid pieces of metal connected by flexible and elastic joints. The mathematical manifold is continuous so the plates are imagined to be infinitesimal. Attached to each point we imagine an independent tangent inertial space which is a source in which events occur.

In a curved dynamic manifold the orientations of these flat spaces vary in space and time. We imagine path through the manifold moving from tangent space to tangent space controlled by a function called the *connection* which encodes the curvature of the space. The theory of relativity derives a *metric* from the connections. The effect of the messages in the gravitational network is to control the space-time intervals between events. We find that a body falling freely in a gravitational field follows the longest space-time path called a *geodesic.* The orbits of satellites are the paths of free fall in the gravitational field of Earth

As with all mathematical derivations of functions in calculus, we start with a discrete finite version of the result we are seeking and then pass to a limit. We may see chain mail as a network of flat sources communicating with one another through the hinges represented by differential operators. Although the continuous representation of the differential manifold is mathematically convenient, it remains an open question whether space-time and gravitation are quantized. Certainly the particles occupying the universe are quantized. Quantum field theory has yet to be successfully extended to gravitation.

As we go to the limit, it is assumed that the differential function which communicates between tangent spaces remains definite and computable, so there appears to be no problem for the network point of view in going to the transfinite continuous limit.

We might ask why space is four dimensional. The answer may be, as designers of networks know, that three dimensions of space and one dimension of time are sufficient to construct a network of points each connected to all the others without any crossed wires. This is not possible in two spatial dimensions, and four spatial dimensions are redundant, so if spacetime is the result of evolution by natural selection, three spatial and one time dimension is satisfactory.

Newton constructed his theory of gravitation in a fixed Euclidean space whose presence and maintenance he attributed to the traditional God outside the universe. The differentiable manifold applied by Einstein is self sufficient and does not require outside divine support, consistent with the idea that the Universe can explain its own structure.

3.4.3 Quantum networks

All processes in the universe involve the transformation of information. A transformation is a process that converts information from one representation to another. If you are reading this on paper, the ink marks on the paper are transformed into modulated light rays which are transformed in your retinas into digital voltage spikes in your optic nerve which are transformed through the layers of neurons in your brain into an understanding of what these marks mean.

A symmetry is something which stays the same when other things change. A sphere is symmetrical because no matter how we turn it it looks the same, and it is impossible to tell if it has moved. The only way to to show that it moves is to break the symmetry by marking a point upon it. Algorithms are symmetries, they stay the same when their variables are instantiated with different values (Neuenschwander 2011, Auyang 1995). Symmetries serve as a modern solution to the ancient problem of universals. The basic universal symmetries are reflected in the conservation of action, energy and momentum, which we may see as boundaries that confine all transformations in the world. We may understand Aristotle's technical terms like potency and act as symmetries, universals that apply to an infinity of concrete situations.

Rational transformations of information change the form of the information, but preserve its meaning. The meaning of this text is preserved as it flows through the physiological layers in a brain that lead understanding. The texts, photos, music and videos that we transmit over the internet look the same at both ends of the transmission line, but they undergo a wide range of transformations on the way.

As I have noted, all fundamental particles fall into one of two classes known as *fermions* and *bosons.* Fermions are structural particles that act as sources in the universal network. They obey the

Pauli exclusion principle which express the fact that no two identical fermions can exist at the same point in space-time. Fermions are characterized by having half-integral *spin* (Streater and Wightman 1964).

Bosons, on the other hand, serve as communication particles. They are characterized by integral spin and any number of identical bosons may exist at the same point in space-time, enabling, for instance, the intense pulses of light produced by a laser.

Photons are the bosons which enable fermions like electrons and protons to communicate with each other, forming atoms, molecules, minerals, and all the other forms of existence that we encounter in everyday life, including ourselves.

As described in chapter 2.3 the observable Universe is built from fundamental particles that communicate with one another and bind into more complex structures through four forces. All particles respond to gravitation, which is a long range force that binds the whole universe together into a complete whole. Atomic nuclei are bound together by the strong and weak forces. Most of the larger scale structure of the universe, which includes ourselves, is bound by the electromagnetic force.

The modern standard view in physics that the ‘hardware’ on which the universe runs on are the fields described by the ‘standard model’, an application of quantum field theory. I am not concerned with the details of what happens behind the scenes in quantum theory. We can understand a quantum interaction as a communication source just as we understand a person as a source without knowing their mental processes or the language they are speaking. We understand the operation of the universe as a network of such sources, communicating by exchanging observable fundamental particles which we understand in the communication theoretical sense as messages.

Given the universality of network structure, this text itself may also be interpreted as a message constructed from an enormous number of quanta of action, and taking the analogy further, I may consider myself as a particle which exists moving through space-time from the event of my creation to the event of my annihilation. In chapter 2 I give a rough estimate of the number of quanta of action executed by a human life (2.3).

3.4.4 Neural networks

Networks are the foundation of mind. This fact is clearly established by the observation that the human mind is a product of the human neural network. Our minds are interfaced with the rest of the world at the input end by the sensory transducers that monitor both the world around us and the physiological condition of our bodies. The output of our neural network controls the physical motion of our muscles and the processes which maintain the internal chemical regime keeps the large variety of our constituent cells alive and functioning.

Life is a electrochemical process based on insulating membranes and ionic motors which create and utilize electrical potentials across the membranes. This system is closely analogous to the techniques of electrical engineering. Multicellular plants rely on chemical signalling to coordinate the operations of individual cells. All but the simplest of animals use neural networks, both for internal housekeeping and for interaction with the world around them.

Neural networks are constructed from neurons, cells (sources) adapted to receive, process and transmit electrical signals. They comprise a cell body, a system of input fibres known as dendrites which may be connected to sense organs or other neurons, and an output fibre, the axon which branches to connect to other neurons or motor organs such as muscle and endocrine cells. The connectivity in the network is high. A neuron may have many inputs and output to many other neurons or motor cells. Neurons fall into three classes, sensory neurons which provide input to the neural network, motor neurons which convey the output of the network to effectors, and interneurons, which transform sensory input into motor output.

Signals are transmitted along the fibres in the neural network by a discrete active electrical symbol known as an action potential, a discrete voltage spike which propagates along the fibre at quite high velocity. All these action potentials are effectively identical, like the digits in a computer network. Their information content is a function of their frequency.

The principal functional connections between neurons and the fibres connecting them are *synapses.* A synapse is a complex structure which, on receiving an input from a connected fibre, releases neurotransmitters which interact with the membrane of the neuron. This interaction may be excitatory or inhibitory. The neuron algebraically integrates this input taking into account the “weight” associated with each synapse. When it reaches a certain threshold it “fires” sending an action potential along its axon.

Processing and memory in a neural network are modulated by “synaptic weights” which are a measure of the level of influence, positive or negative, a particular synapse may have on the neuron to which it is connected. The details of a neural network may be extraordinarily complex, there are many different neurotransmitters and many varieties of cells which perform auxiliary functions associated with the neural network.

One of the principal research tools used to understand the functions of neural networks are computer systems which model the synaptic connections in a network and enable the adjustment of synaptic weights by various training algorithms in attempts to model the behaviour of various subsets of neural networks. This work is of great interest to the artificial intelligence community, but is far from achieving equivalence to the human brain.

The ontological development of an individual human human brain poses an interesting problem in network creation. An important source of formal guidance in the develop of any living creature is the *genome*. The expression of the genome occurs in the context of a living cell, and depends on transformations executed by the physical and chemical processes embodied in the cell. These are reducible in the first instance to electrodynamics.

Formally, programmed deterministic development is subject to the cybernetic principle of requisite variety. This law establishes the condition for completeness and computability that render any process deterministic enough to have a high probability of good success.

The total human genome comprises some three billion base pairs, each of which carries a maximum of two bits of information for a total of 6 gigabits per genome.

The human nervous system comprises some 100 billion neurons each with possibly 1000 connections to other neurons.

In the specification of a standard engineered computer network, every physical connection is precisely specified by source and destination. Measured in bits of information this is at a minimum twice the logarithm to base 2 of the number of connections. Such precise specification in the case of the n connections of the human nervous system is $n \log n$, where n = 100 billion (neurons) x 1000 (connections per neuron), ie 10^{14}. $n \log n$ is therefore about 10^{16} bits, far in excess of the information content of the genome.

It is necessary, therefore, that some other mechanism must be available to account for the connective structure of the brain, which is to say that to a large degree this system must define itself. This requirement reveals that the human brain must have a self-structuring property.

The explanation appears to be a form of evolution by natural selection. The neurons in an infant brain seek out synaptic connections with one another, a process which is to a large degree random. There follows a process of pruning which continues through the teenage years, eliminating connections found to be unnecessary for processing environmental inputs..

As well as determining the wiring of the brain over a period of years, experience determines the synaptic weights connecting neurons. Changes in weight may occur in milliseconds during the real time processing of speech, and over a lifetime during the acquisition of knowledge and experience. The physical development of a brain is thus closely related to learning and serves as a microcosm of the development of the universe.

3.3.5 Human networks

On close inspection, there is very little difference between genetic evolution and cultural evolution. Cultural memory is stored in the minds of people and cultural artefacts of all sorts.

Articles and books in the literature correspond to genes. Genes are decoded by a living cell in order to generate a new creature with a new set of genes. In a similar way elements of the cultural literature are processed through human minds to develop new contributions to the culture. This processing is guided by the experience of individuals, and the community as a whole (peer reviewers) selects those cultural codes or languages that are worthy of reproduction.

Each new language or code has an ontological function, generating a new form of human society. It is here we find the emergence of new moral and political codes. In business we often find legislated corporate codes that define a space of business relationships.

The creation of culture as recorded in the documentation may serve as a paradigm for the creation of the world recorded in cosmology and palaeoontology. This idea was mooted by the Jesuit priest and palaeontologist Pierre Teilhard de Chardin who coined the term *noosphere* for the layer of structure emerging in human minds built on the biosphere (Teilhard de Chardin

1980). Physicist have long searched for a *unified field theory* that encompasses the four fundamental communication codes of nature, gravitation, the strong and weak forces and electromagnetism in one picture. From a more general point of view, the cosmological network embraces all forms of communication and processing (encoding) and serves as a generic unified field theory.

With this insight, I proceed in the next chapter to use the network paradigm to suggest that the universe is capable of all the roles attributed to the traditional God.

Chapter 4: Value

Outline

* * *

4.0 Abstract

This chapter completes the argument by showing that the network model, as implemented in the observable universe, shares some of the attributes the classical God. The Christian God is understood first as the infinite, omniscient and omnipotent creator and controller of the world. It is also understood as the supreme value, the apotheosis of human existence, (*Genesis*, 1:1, *ST*, I II, 1, 4).

The first part of the chapter claims that the three quoted attributes of God apply to the Universe revealed by science. The network model enables us to conceive of the Universe as filling the logical space of consistency. This reflects Aquinas's definition of God, pure act, the realisation of all possibility. Outside this space is inconsistency, that is nothing.

The second part of the chapter deals with the relationship between God as understood in this thesis and ourselves, individuals of the species *Homo sapiens.*

Aquinas, following Christian doctrine, holds that God created the world to share its goodness with humanity. This occurs in two

stages: The first is the *Incarnation*. It is believed that God became human in the person of Jesus of Nazareth, granting us some vision of divinity (*ST* III, 1, 1). The second is the vision of God enjoyed by the blessed in the next life (*ST* I II, 3, 8). Implicit in this doctrine is that the goodness of God is the ultimate human value.

In the picture presented here each of us is divine insofar as we are a subsystem of the divine Universe. It follows that all our experience is experience of God. In reality, however, this experience is not all bliss. The states of divine perfection imagined by Christian theologians cannot be consistently realized. Instead we must deal with the complex environment in which we find ourselves. I conclude this thesis with the observation that if the world is itself divine we can expect no help from an outside God but must take responsibility for our own welfare.

4.1 The beatific vision

Aquinas maintains that *it is impossible for any created intellect to see the essence of God by its own natural power* (*ST* I, 12, 4). The *post mortem* vision of the essence of God, known as the beatific vision, is only believed to be possible by special grace of God. It seems highly improbable that the Christian eschatological promise will be realised for any of us. Nevertheless we have evolved on Earth and our sensory and intellectual abilities are closely turned to our environment, so we are well equipped to sense and appreciate the divine beauty that surrounds us. We may not be able to understand the essence of the universe, but survival requires that we know our local situation well right down to details like crossing the road.

4.2 Computation and communication

A remarkable features of Thomas Aquinas' appropriation of Aristotle for the elaboration of Christian theology is the simplicity of the arguments Aquinas drew from Aristotle, *The* Philosopher. Aquinas built much of his theology using just six Aristotelian ideas, *matter, form, agent, purpose*, *potency* and *act.* Modern ideas of equivalent universality and power are *communication* and *computation.* Both these sets of terms are universal symmetries.

The computer network developed and exemplified above is intended to serve as a simple modern model of the Universe to replace Aristotle's path to divinity.

Aquinas notes in the preface to the *Summa* that his work is intended for beginners as well as experienced students:

> . . .catholicae veritatis doctor non solum provectos debet instruere, sed ad eum pertinet etiam incipientes erudire (Aquinas, 1962 page 3).

In addition to making theology simple for beginners, Aquinas had another motive for simplicity. Although his approach to theology was quite new in the Catholic academic *milieu* in which he worked, he introduced no new doctrine. Everything he wrote complied precisely with tradition, so his arguments simply clarified and reinforced rather than criticized beliefs which were thousands of years old in the Hebrew and Christian traditions.

The task here, nearly 800 year later, has been justify a break from this ancient tradition. The first step in this, direction undertaken in previous chapters, has been to contrast the universe of Aristotle with the universe as we now know it. The second step it to show that the traditional attributes of God, infinity, omniscience and omnipotence are nevertheless still visible in the universe revealed by science.

4.3 The Universe is infinite

4.3.1 God is infinite

The term *infinite* has two related meanings, *very big* and *without boundary.* Aquinas asks if God is infinite, and answers yes. His argument is based on Aristotle's *hylomorphism* (Ainsworth 2016):

> . . . form is not made perfect by matter, but rather is contracted by matter; and hence the infinite, regarded on the part of the form not determined by matter, has the nature of something perfect. Now being is the most formal of all things, . . . Since therefore the divine being is not a being received in anything, but He is His own subsistent being . . . it is clear that God Himself is infinite and perfect (*ST I, 7, 1*).

From Aquinas' point of view, God is infinite because it is without boundary. Modern cosmology supports a similar argument from the large scale structure of space-time described by the general theory of relativity. This space is *curved* and closed in the sense that one can travels an unlimited spatial distance forward in time and come to no boundary, unless one crosses the event horizon surrounding a black hole.

Going back in time (which is theoretically but not practically possible) one also comes to a boundary to the universe known as the initial singularity (Hawking & Ellis 1975). I have noted above that this point is formally identical to the traditional God, being both absolutely simple and the source of the Universe. The principle difference is that while traditional theology holds that God created a Universe distinct from itself (and could have made it very different), the cosmological view is that the Universe emerged within the initial singularity through the *big bang.*

Insofar as we understand that there is nothing outside the Universe, so that it is not contained in any way, Aquinas' argument for infinity given above still holds. In this section I wish to argue that looking from *inside* the Universe, we may also see that it is infinite.

4.3.2 Syntactic communication

Nowak pointed out that unlike most of the communication between other animals, human communication is *syntactic* making *infinite use of finite means* (2.8.1). This strategy introduces an exponential increase in the detail that we can communicate. While one may grunt in many tones of voice, the human feeling that can be communicated by speech and gesture is very much greater.

4.3.3 A computer is a syntactic machine

Turing's computer gets its power by taking advantage of syntax (3.3.1). The working memory of the computer is an ordered countably infinite string of locations (*squares*). As with the natural numbers, if the machine runs out of locations, it is free to add another. Modern computes and networks differ in detail, but they remain deterministic machines whose behaviour is determined by ordered sets of symbols.

In mathematics, syntax enables us to construct numerals to represent any cardinal number by forming ordered sets of digits. Toward the end of the nineteenth century, George Cantor set out to use syntactic methods to represent the cardinal of the continuum and realised that ordered sets of symbols could be used to represent anything representable (1.9.15).

4.3.4 On continuity and transfinity

Aquinas' argument is very simple and Aristotelian, but modern mathematics has a lot more to say about infinity which is relevant to the structure of the Universe. It enables us to represent a succinct abstract picture which expresses the idea that we live in an infinite dynamic system which may be understood as the mind of God.

Isaac Newton invented *calculus* to derive, explain and calculate his *System of the World* (Newton 1687, 1972). Calculus models continuous motion in space and time by considering the ratio of distance travelled over time taken in progressively shorter and shorter intervals. Physically is seems quite reasonable, but mathematically is raised many of the problems first studied by Zeno in the fifth century bce (Huggett 2018). Many mathematicians, particularly in the nineteenth century tried to produce a rigorous account of calculus and the related subjects of continuity and real numbers. Much of this work modelled the continuum as an infinite set of discrete points, which led Georg Cantor to investigate the *cardinal of the continuum*, the number of points it takes to constitute a continuum. Like Newton, he invented a new branch of mathematics in the process, *set theory.*

He defined a *set* (aggregate, *Menge*) as *any collection into a whole M of definite and separate objects m or our intuition or our thought.* The beauty of a set is that it is not only a finite container which can be talked about and manipulated, but it can contain an infinite number of elements, its *cardinal,* effectively putting handle on infinity.

The basic computational process in set theory is the establishment of one-to-one correspondences. Two sets have the same cardinal if each elements of one can be matched with corresponding element of the other and none are left over on either side.

In addition to their cardinal number Cantor's sets have one other property, an *ordinal type. The ordinal type of M is itself an ordered aggregate whose element are units which have the same order of precedence amongst one another as the corresponding elements of M, from which they are described by abstraction*.

Cantor began with the infinite set ***N*** of all natural numbers. The cardinal of this set cannot be a particular natural number, because we can always add 1 and get a larger number so he named the cardinal of the set $\aleph_0$, using the first letter of the Hebrew alphabet. He called $\aleph_0$ the first transfinite number. He then goes on:

> [496] To every transfinite cardinal number *a* there is a next greater proceeding out of it according to a unitary law, and also to unlimitedly ascending well-ordered aggregate of transfinite cardinal numbers, $\{a\}$, there is a next greater proceeding out of that aggregate in a unitary way. (Cantor 1955 page 109)

This *unitary law* is based on the fact that there are many ways to order a given set by constructing combinations and permutations of its elements.

4.3.5 The Cantor theorem

Let us suppose the existence of the power set $P(S)$ of S, the set of all subsets of S. $P(S)$ is in effect the collection of all the combinations of the elements of S. The *Cantor theorem* then asserts that the cardinal of $P(S)$ is greater than the cardinal of S (Hazewinkel I, 501).

Cantor's hope of representing the cardinal of the continuum was dashed by Cohen's argument that the continuum hypothesis is independent of set theory (Cohen 1980). The heart of the problem is that the concepts of *set* and *cardinal number* are independent of one another. Nevertheless, set theory has become a foundation of mathematics and shows how we can model a transfinite computer network.

Aristotle studied space and provided a definition of continuity in his physics which supposes that two lengths are continuous if their ends overlap:

> . . . things are called continuous when the touching limits of each become one and the same and are, as the word implies, contained in each other: continuity is impossible if these extremities are two. This definition makes it plain that continuity belongs to things that naturally in virtue of their mutual contact form a unity. And in whatever way that which holds them together is one, so too will the whole be one, e.g. by a rivet or glue or contact or organic union. (Aristotle, *Physics,* 227a10 *sqq*.)

This definition is reminiscent of Aristotle's syllogistic logic in which the premises leading to a conclusion overlap by a middle term. (Aristotle, *Prior Analytics*, 24b18 *sqq*.). This suggests *logical continuity* which is instantiated in a mathematical proof, a computation or an error free communication.

Here I use the concept of logical continuity to apply Cantors insights to the structure of the universe using a *transfinite computer network* as a backbone for the idea that the universe is a divine mind.

We begin with the formal mathematical fact that the cardinal of the set of Turing machines, that is the cardinal of the set of computable numbers, is equal to the cardinal of the set of natural numbers. We can therefore create a one-to-one correspondence between computers and natural numbers and create different networks by combining the computers in different ways just the power sets we use to prove Cantor's theorem are different combinations of natural numbers. We imagine the computers as sources connected by communication channels.

Here we can apply Cantor's principle of finitism, and assume that the first transfinite cardinal, $\aleph_0$ is equivalent to any number from 1 to the number of quanta of action in the lifetime of the universe (Hallett 1984, page 32). The $\aleph_0$ quanta of action can be ordered in $\aleph_0!$, that is $\aleph_1$, different ways. As Cantor noted, we need not stop there but can repeat this process to generate $\aleph_2$, $\aleph_3$ and so on without end, a structure large enough to describe any universe.

Cantor's theory upset some theologians who felt that infinity is the unique attribute of God and there can be no 'created' infinity. This problem was avoided by Cantor's tacit use of formalism. Although in reality all information is represented physically, mathematicians are still free to imagine that the symbol ***N*** may stand for anything, such as the infinite set of natural numbers.

Much of Cantor's work was theologically motivated, and he set out to define an absolute infinity which was to be characteristic of God. He found that the existence of such an infinity was not self consistent, something now known as Cantor's paradox. Cantor had proved that every set can generate a larger set. This must hold for any candidate absolutely infinite set, which is therefore no longer absolutely infinite. (Dauben 1990, Hallett 1984).

From this we may conclude that transfinite mathematics does not have an element corresponding to God. Instead it has a series of elements which may approach but never reach the immensity of God. We can talk about these subsets of the whole (sometimes called universes of discourse) without contradiction. Further, Cantor's theorem guarantees that no matter how large a universe of discourse we decide to study, it will remain always a subset of the strictly greater set arising from the Cantor expansion of our chosen universe. It may be that this network structure has sufficient power to represent every quantum of action in the life of the universe.

4.4 The Universe is omniscient

4.4.1 Knowledge and spirituality

Aquinas explains God's knowledge using the same argument that he used to show that God is infinite: it is unconstrained spirituality:

> . . . sense is cognitive because it can receive images free from matter, and the intellect is still further cognitive, because it is more separated from matter and unmixed, as said in *De Anima* iii. Since therefore God is in the highest degree of immateriality . . . it follows that He occupies the highest place in knowledge. (*ST* I, 14, 1).

As suggested in chapter 1, this argument does not carry weight in the modern understanding of representation and information which is verified by the practical engineering of information processing and communication machinery.

The network model I propose is also a classical theory in the sense that it takes the observed particles of the universe as given and does not go behind the scenes to the explore the quantum field theories that attempt to explain the nature and behaviour of the observed particles. I have simply taken for granted that the world of particles is divided into boson and fermions, and that the fermions communicate with one another in a logically consistent fashion by exchanging bosons (2.3). This consistency is supported by observation.

A typical and well studied event in quantum physics is the absorption or emission of a photon by an atom. This phenomenon is the subject of quantum electrodynamics (QED), a well developed field theory that describes everything we observe and experience in daily life except gravitation.

A foundation of our understanding of the quantum world is that the steps between physical quantum states are always an integral number of quanta of action.

The interaction of a photon and an atom involves one quantum of action. The photon has spin 1 (ie one quantum of angular momentum) and the electron which absorbs or emits it has its orbital angular momentum or it spin changed by one quantum. Angular momentum is conserved, so gain and loss add up to 0.

The role of QED is to compute the energy change involved in this interaction. The energy carried by the photon is a function of its frequency, $E = hf$. The energy change associated with the electron is a complex function of its relationship to the atomic nucleus and the other electrons in the atom. One explanation of this interaction is based on networks called *Feynman diagrams* (Veltman 1994). Photon and electron only interact if the resulting energy change for the electron is close to the energy of the photon.

In general we learn about fundamental particles by watching them interact with one another. Machines such as the Large Hadron Collider are in effect large microscopes, which take advantage of the uncertainty principle. By increasing the energy of collision, we increase the time resolution. By increasing the collision momentum, we increase the spatial resolution. With the biggest of these machines we can explore the composition of very small complex particles like protons.

In the network model, we assume that the behaviours of the particles are logical and consistent without taking account of the actual mechanisms of interaction. This is similar to the notion that people can talk to one another with no idea of the physiology of speech.

4.4.2 The mechanism of intelligence

From the network point of view, the mechanism of intelligence seems analogous to the mechanism of evolution. The principle difference being the time factor. Evolution works by genetic variation and natural selection. Intelligence arises from variation by imagination and selection of consistent representations of the phenomena of interest. Network structure makes this process possible. Random network connections can introduce variation. Network connections bring contradictory messages into contact, forcing extinction or correction. In the philosophical network for instance, opinions are brought into contact with a view to deciding whether or not they are consistent with one another and with the real and philosophical worlds.

4.4.3 *Insight*

We understand and act on most of our sensory input almost immediately. It does not take much thought to see how to return the ball in a game of tennis, although the execution may be more problematic. In more complex cases understanding may come slowly or not at all. The history of science demonstrates that it may take the collaboration of many people centuries to arrive at a satisfactory understanding of phenomena like the shining Sun.

The Catholic theologian Bernard Lonergan used a model of insight to argue for the distinction of the classical God from the world (Lonergan 1992) (1.6). He argues that the divinity must be completely intelligible but that the universe of experience is not so because it embodies *empirical residue,* phenomena without meaning or explanation (*op. cit.* pp 50-56*,* 695 *sqq*) .

It was the apparent failure of Lonergan's argument which led me to see that the traditional Catholic notion of a God other than the world is not necessary.

4.5 The Universe is omnipotent

4.5.1 God is omnipotent

Aquinas attributes omnipotence to God, meaning that it can do anything that does not involve a direct contradiction:

> . . . God is called omnipotent because He can do all things that are possible absolutely; . . . For a thing is said to be possible or impossible absolutely, according to the relation in which the very terms stand to one another, possible if the predicate is not incompatible with the subject, as that Socrates sits; and absolutely impossible when the predicate is altogether incompatible with the subject, as, for instance, that a man is a donkey (*ST* I, 25, 3).

I understand this to be the only constraint on the Universe. The random variations of the evolutionary process enable the Universe to explore all possibilities. The process of selection prevents the propagation of possibilities which are inconsistent with continued existence in their environment.

We may see the power of survival from two points of view, which I will call violence and subtlety.

Violence involves the release of large amounts of energy in a very short time, some sort of explosion. The big bang is considered to be the most violent event imaginable, followed by supernovas. Despite their high energy, these events do not necessarily break any laws of nature but probably follow the laws of high energy physics in the same way as a high energy chemical explosion does not break the laws of chemistry. In a consistent universe, the laws of nature are such that to "break" them is effectively to move out of the realm of consistency into non-existence. Nevertheless high energy structures like a speeding bullet can break low energy structures like a brain by destroying them. This breaks the laws of brains, but not of bullets.

By subtlety I mean the power of being able to understand the details of a situation well enough to manipulate it toward a successful outcome. Many believe that the traditional God has this power, so that no matter how evil situations may appear to us, the divinity has arranged things for the better. This may or may not be true. People we hold in high esteem are those with the social and political skills to defuse potentially violent situations and prevent possible damage.

4.5.2 Does formalism drive the world?

Aristotle, Aquinas, the Scholastics and Catholic theologians often proceed as though logical thought and argument can reveal the true nature of the world. Theologians often use ancient texts as criteria of truth on the hypothesis that the authors of these texts have been inspired by God and their writings therefore have evidential value.

An alternative view is that all sacred texts are hypothetical fictions based on their authors' experience and imagination, having historical rather than scientific value. A similar problem arises when we come to apply mathematics to the understanding of the world. For most of accessible intellectual history, mathematics has been considered to be a body of irrefutable truth. This view has weakened with the advent of non-Euclidean geometries and the formalist interpretation of mathematics. Nevertheless, insofar as we trust logic, we can rely on mathematical proofs if (and only if) their hypotheses are fulfilled.

Insofar as nature and mathematics are logically consistent, we can therefore expect them to operate in parallel. Einstein revealed that while Euclidean geometry applies to infinitesimal regions of space-time, it does not fit the large scale of the universe. He was able, nevertheless to devise a spacetime structure which appears to mimic the universe exactly. This may lead us to suspect that the Platonic form of the general theory may be the driver of the physical universe.

4.5.3 Why did the big bang go off?

The initial singularity, like the traditional God, exists before the emergence of space and time and so is naturally immutable, eternal, perfect and all the attributes traditionally considered to be appropriate to the divinity. Aquinas and others argue for this position on the basis that God is pure act, without any admixture of potency. It is the realization of all possibility. This argument relies in turn on the Aristotelian axiom that no potency can actualize itself.

In the modern era of physics, potential has become equivalent to actuality, an equivalent form of energy, and it may be the case that the sum of the potential and actual energy in the universe is zero. It is therefore possible for the initial singularity to become the world we experience. We might see Cantor's theorem as an expression of the *via negativa,* so that it could be argued that it would not be consistent for the universe to remain simple, but it must, like the transfinite numbers, move toward unlimited complexity, which appears to be its tendency.

4.5.4 What's so special about Earth?

Observations from spacecraft have revealed that a large proportion of stars are accompanied by planets, but that very few of these planets are in orbits which allow the existence of liquid water, and so life as we know it. It seems unlikely, given the finite velocity of light, that we will ever make contact with scientifically and technologically advanced forms of life like ourselves. Why are we as we are?

The answer lies in the nature of our environment.

Thermodynamically, the Earth is in effect a heat engine, working between the temperature of the Sun, about 6000 K and the temperature of space, about 3 K. An ideal heat engine working on the Carnot cycle is reversible, meaning that it conserves entropy. The entropy it receives from the hot source is rejected to the cold source and the energy difference is made available as zero entropy mechanical energy. In other words, given a temperature difference, the Carnot cycle can reproduce the zero entropy conditions of the initial singularity, which is in effect the epitome of order.

At the same time, the surface of Earth is a gentle and chemically benign environment by the standards of the wider universe, so that delicate ordered low entropy structures are readily maintained by evolutionarily feasible levels of error correction, particularly by reproduction guided by carefully conserved genes. The same mechanism appears to work in a moral way, at least statistically, to reduce the level of violence within the human species so that we are learning to create more and more complex and delicate social organizations which improve the welfare of many people (Pinker, 2011).

4.6 Navigating in the divine world

4.6.1 Failure modes and evil

The evolutionary process has not been continuous but punctuated at intervals with violent event such as supernovae and the formation of black holes. The palaeontological record on Earth shows many extinctions caused by changes in the atmosphere, climate, meteorite impacts and volcanoes. In general the initial effect of these events is to drive systems back to simpler and more primitive times from which the evolutionary process begins again to adapt to the new situation. We see a similar pattern in human development, plagues, famines and wars destroying civilizations, providing opportunities for others to grow in their place (Diamond 2004).

From a human point of view, these setbacks may be seen as evils. Traditional theologies, often based on omnipotent and benevolent deities, find these evils difficult to deal with and have often invented anti-deities to account for evil events. In the Universe known to science, however, such negative outcomes are natural and must be understood, foreseen and dealt with.

4.6.2 Value

In an evolutionary world the basic value is survival. Every creature that currently exists can trace a succession of ancestors through millions or billions of generations back to the beginning of life. It may be that in the early days all forms of life became extinct and then life began again, but we can be fairly certain once life became well established has flourished continuously for some billions of years. Millions of species would have come and gone, but life has continued unbroken.

For humans in a theocratic world, they key to survival is to value the same thing as the god values. Since it is often difficult to know what the god wants, priests are likely to assume the role of instructing the people. Since the priests can no more see the invisible God than the people, this situation can lead to profound misunderstandings of the nature of the world. Consequently many empires have flourished and failed and many believe that our current state of existence is fragile because we have mistreated our environment.

Strategies for survival are are very widely varied, but on the whole we find that every species occupies a relatively exclusive ecological niche. As the environments change, species must be able to evolve fast enough to track these changes, and extinction becomes more probable if they cannot keep up.

Over the last few centuries, our species has expanded very rapidly, principally because science and technology and capital investment have made it possible for us to steer more of the world's resources toward ourselves and overcome many of the public health problems that lead to short and unhealthy lives. We are becoming a danger to ourselves and we are becoming aware of this danger.

4.6.3 Divine providence

For much of human history many people have believed that the conditions of their lives are under divine control and priesthoods have recommended that people use rather magical procedures as prayer and sacrifice to encourage the gods to be benevolent and helpful. In a divine universe governed by predictable laws of nature, however, we can play a much more direct role in our own salvation. The same knowledge and skills that have contributed to our almost unlimited success can, if we are adequately motivated, be applied to reduce our impact on the planet. If this thesis reflects reality, we can no longer rely on the providence of an invisible deity. We must learn to look after ourselves since there is no outside miraculous help available. The Earth is our habitat. We live in God so that scientific theology is a key to life. If we value our own lives, we must value the resources upon which we rely to live.

Conclusion

This thesis is a move toward the secularization of theology. To bring it, at last, into the pale of science. The story here is a theological hypothesis: Can we complete the task, begun by Isaac Newton, of bringing the heavens down to Earth?

My starting point is the first part of the *Summa theologiae* of Thomas Aquinas, which deals with God, creation and creatures, including people and angels. This work is principally based on the Christian Bible, and the works of Aristotle and the Christian Fathers of the Church (Migne 1884-1882, 1857-87).

My principal method is to compare the arguments Aquinas has taken from Aristotle to modern scientific views. The central theme is that the Universe began as a simple being identical to the simple God described by Aquinas in the *Summa* (Aquinas, *ST* I, 3, 7).

Whereas God created the world outside itself, it seems that that the

Universe evolved within God and so is effectively divine. The only theological constraint placed on the power of God is that it cannot create an actual contradiction. I place this logical constraint in the context of a logical computer network. I argue that this system provides a logical frame for evolution which can account for the world we observe and are.

The study of evolution shows that the key to the *Struggle for Life* is not necessarily power and violence, but may also be cooperation and intelligence. This is suggested by the fact that primitive unicellular creatures evolved into multicellular creatures like ourselves in which trillions of individual and quasi autonomous cells work together for their mutual benefit. Since the evolutionary paradigm is independent of scale, the same tendency leads us multicellular individuals to cooperate for our common good. Detailed examination of this cooperation is the subject of morality and politics, studies which would develop modern scientific versions of the second and third parts of the *Summa Theologiae*.

Bibliography

Ainsworth, Thomas, 2016, (Stanford Encyclopedia of Philosophy), Form vs. Matter, (accessed 16/8/2018) : available from https://plato.stanford.edu/entries/form-matter/; Internet.

Aquinas, Thomas, (2019) *Opera Omnia*, (accessed 11/3/2004) : available from http://www.corpusthomisticum.org/iopera.html; Internet.

_______, (1962) *Summa Theologiae*, Editiones Paulinae, Rome

_______, (1265-1274, 1981) *Summa Theologica* (translated by Fathers of the English Dominican Province), Allen, Texas: Tabor Publishing.

-------, *Commentary on Aristotle's Physics:* Book VII, (accessed 20/5/2019) : available from https://dhspriory.org/thomas/Physics7.htm; Internet.

--------, *Summa*, I, 1, 2, Is sacred doctrine is a science?, (accessed 23/12/2017) : available from http://www.newadvent.org/summa/1001.htm#article2; Internet.

______, *Summa,* I, 2, 3: Does God exist?, (accessed 9/6/1999) : available from http://www.newadvent.org/summa/1002.htm#article3; Internet.

______, Summa, I, 3, 7, Is God altogether simple?, (accessed 11/27/2017) : available from http://www.newadvent.org/summa/1003.htm#article7; Internet.

______, Summa, I, 8, 3, Is God everywhere by essence, power and presence?, (accessed 12/8/2019) : available from http://www.newadvent.org/summa/1008.htm#article3; Internet.

______, Summa: I, 14, 1, Is there knowledge in God?, (accessed 15/11/2016) : available from http://www.newadvent.org/summa/1014.htm#article1; Internet.

_______, Summa I, 25, 3, Is God omnipotent?, (accessed 8/19/2016) : available from http://www.newadvent.org/summa/1025.htm#article3; Internet.

_______, Summa, I, 75, 2, Is the human soul something subsistent?, (accessed 14/10/2019) : available from http://www.newadvent.org/summa/1075.htm#article6; Internet.

_______, Summa, I, II, 1, Man's last end, (accessed 10/11/2016) : available from http://www.newadvent.org/summa/2001.htm; Internet.

_______, Summa, I II, 3, 8, Does man's happiness consist in the vision of the divine essence?, (accessed 14/4/2004) : available from http://www.newadvent.org/summa/2003.htm#article8; Internet.

_______, Summa, III, 1, 1, Is it fitting for God to become incarnate?, (accessed 17/10/2019) : available from http://www.newadvent.org/summa/4001.htm; Internet.

Aristotle, 1977 *Metaphysics X-XIV, Oeconomica and Magna Moralia*, Cambridge Massachusetts, London: Harvard University Press, William Heinemann Ltd.

Aristotle (translated by W. D. Ross), *Nichomachean Ethics,* (accessed 5/6/2019) : available from https://ebooks.adelaide.edu.au/

a/aristotle/nicomachean/; Internet.

Ashby, W Ross, (1964) *An Introduction to Cybernetics*, Methuen, London

Aspect, Alain, P. Grangier, and G. Roger 1982 Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities. Physical Review Letters 49: 91-94.

Augustine, *The Trinity*, (400-416, 1991, 2010) New City Press. Barile, Margherita, New York

Burnet, John, (1908, 2015) *Early Greek Philosophy*, Palala Press, New Yor.

Catholic Catechism, p1, s2, c1, a1, p7, The Fall, (accessed 5/12/2017) : available from http://www.vatican.va/archive/ENG0015/__P1C.HTM; Internet.

________, p1, s2, c1, p4, III. "The world was created for the glory of God, (accessed 4/11/2016) : available from http://www.vatican.va/archive/ccc_css/archive/catechism/p1s2c1p4.htm; Internet.

Cooper, Alan, Alan N Williams & Nigel Spooner, When did Aboriginal people first arrive in Australia?, (accessed 7/8/2018) : available from https://theconversation.com/when-did-aboriginal-people-first-arrive-in-australia-100830; Internet.

Epsilon-Delta Proof, Wolfram MathWorld, (accessed 5/14/2010) ed. Eric W. Weisstein. URL = <http://mathworld.wolfram.com/Epsilon-DeltaProof.html>

Cantor, Georg, (New York) *Contributions to the Founding of the*

Theory of Transfinite Numbers, New York Dover, New York

Carnot, Sadi, (1824, 1977) *Reflections on the Motive Power of Fire: and other papers on the second law of thermodynamics by E Clapeyron and R Clausius Gloucester*, Massachusetts: Peter Smith Publisher.

Casti, John L., (1996) *Five Golden Rules Great: Theories of 20th-Century Mathematics - and Why They Matter*, New York: John Wiley and Sons.

Cercignani, Carlo, (2006) *Ludwig Boltzmann: The Man Who Trusted Atoms,* New York: Oxford University Press.

Chaitin, Gregory J., (1975) Randomness and Mathematical Proof Scientific American 232:5 47-52.

__________, (1982) Gödel's Theorem and Information, (accessed 24/8/2017) : available from www.cs.ox.ac.uk › activities › ieg › e-library › sources › georgia; Internet.

__________, (1987) *Algorithmic Information Theory*, Cambridge: Cambridge UP.

__________, (1987b), "Goedel's Theorem and Information" in Information, *Randomness & Incompleteness: Papers on Algorithmic Information Theory*, World Scientific, Singapore, 1987.

Cohen, Paul J., (1966) *Set Theory and the Continuum Hypothesis*, London: Benjamin/Cummings.

Darwin, Charles, (1998) and Greg Suriano (editor), The Origin of Species, Gramercy, New York, 1998.

_________, (1859, 2009) *The Origin of Species by Natural*

Selection, or the Preservation of Favoured Races in the Struggle for Life, Cambridge University Press, Cambridge

Davies, Paul, (1992):*The Mind of God: Science and the Search for Ultimate Meaning,* Penguin Books New York.

Davis, Martin (1982) *Computability and Unsolvability*, Dover, New York

Diamond, Jared (2004) *Collapse: How Societies Choose to Fail or Succeed*, Viking Adult, New York

Dirac, P. A. M., (1983) *The Principles of Quantum Mechanics* (4th edition), Oxford University Press, Oxford

Einstein, Albert, (1905) Zur Elektrodynamik bewegter Körper (On the electrodynamics of moving bodies), Annalen de Physik 17: 891.

_________, On the Electrodynamics of Moving Bodies, (accessed 13/5/2019) : available from https://en.wikisource.org/wiki/Translation:On_the_Electrodynamics_of_Moving_Bodies; Internet.

__________, B. Podolsky, and N. Rosen (1935) Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?, *Physical Review* 47: 777-780.

Faraday, Michael, (2004) *Experimental Researches in Electricity,* Dover Publications, New York

Feferman, Solomon, (1986), and John W Dawson, Stephen C Kleene, Gregory H Moore, Robert M Solovay, Jean van Heijenoort (editors), Kurt Goedel: Collected Works Volume 1 Publications 1929-1936, Oxford UP, New York.

Feynman, Richard P., (1970) *The Feynman Lectures on Physics* *(volume 3) Quantum Mechanics,* Addison Wesley, Reading Massachusetts

_________, and Albert P Hibbs (1965) *Quantum Mechanics and Path Integrals,* McGraw Hill, New York

_________, (1988) *QED: The Strange Story of Light and Matter*, Princeton University Press, Princeton NJ

_________, 2007 *Feynman Lectures on Computation*, Perseus Publishing, Cambridge MA

________, Leighton & Sands, (1971) *The Feynman Lectures on Physics*, III:1 Quantum behaviour, (accessed 25/8/2016) : available from http://feynmanlectures.caltech.edu/III_01.html; Internet.

Finocchiaro, Maurice A., Aspects of the Controversy About Galileo's Trial (From Descartes to John Paul II), (accessed 5/6/2019) : available from www.fundacionorotava.org/media/web/files/page145__cap_04_02_Finocchiaro.pdf ; Internet.

Galilei, Galileo (1957) *Discoveries and Opinions of Galileo: Including the Starry Messenger (1610 Letter to the Grand Duchess Christina)*, New York: Doubleday Anchor

_________, (1954) *Dialogues Concerning Two New Sciences* (translated by Henry Crew and Alfonso de Salvio), Dover, New York

Gellert, Walter, et. al. (eds), (1994) *The VNR Concise Encyclopedia of Mathematics*, Van Nostrand Reinhold, New York

Graham, Daniel W., (2007) Heraclitus Stanford Encyclopedia of Philosophy. URL = < http://plato.stanford.edu/entries/heraclitus/>

Graves, Robert, (1993) *The Greek Myths: Complete Edition*, Penguin Books, London

Hamacher, Duane W., The Memory Code: how oral cultures memorise do much information, (accessed 10/6/2019) : available from https://theconversation.com/the-memory-code-how-oral-cultures-memorise-so-much-information-65649; Internet.

Hallett, Michael (1984) *Cantorian set theory and limitation of size*, Oxford University Press, Oxford

Hartle, James B., (2003) *Gravity: An Introduction to Einstein's General Relativity*, Addison-Wesley, Boston

Hawking, Steven W. and G. F. R. Ellis (1975) *The Large Scale Structure of Space-Time,* Cambridge University Press, Cambridge

Heyes, Cecilia, (2018) *Cognitive Gadgets: The Cultural Evolution of Thinking*, Belknap Press: Harvard University Press, Harvard.

Heath, Thomas L (1956) *Thirteen Books of Euclid's Elements* Dover, New York

Heisenberg, Werner, (1925) On Quantum Mechanical Reinterpretation of Kinematic and Mechanical Relations Zeitschrift fur Physik 33: 879-893.

Hibbert, David Brynn, The way we define kilograms, metres and seconds changes today, (accessed 20/5/2019) : available from https://theconversation.com/the-way-we-define-kilograms-metres-and-seconds-changes-today-117255; Internet.

Hille, Einar, (1973) *Analytic Function Theory*, Chelsea New York

Hinchcliff , Cody E., *et. al.*, (2015) Synthesis of phylogeny and taxonomy into a comprehensive tree of life., (accessed 25/1/2017) : available from https://tree.opentreeoflife.org/about/open-tree-of-life; Internet.

Hobson, M P, G. P. Efstathiou and A. N. Lasenby (2006) *General Relativity: An Introduction for Physicists,* Cambridge UP, Cambridge:

Holy See 1992, *Catholic Catechism p1, s1, c3, a1 I. The Obedience of Faith*, (accessed 4/6/2019) : available from http://www.vatican.va/archive/ENG0015/__PV.HTM; Internet.

Huang, Kerson (1987) *Statistical Mechanics,* John Wiley

Hublin, Jean-Jacques, *et. al.* "New fossils from Jebel Irhoud, Morocco and the pan-African origin of *Homo Sapiens, Nature* 546 (08 June 2017): 7657, 289-292.

Hug, Laura A., *et. al.*, (2016) A new view of the tree of life, (accessed 12/4/2016) : available from http://www.nature.com/articles/nmicrobiol201648; Internet.

Huggett, Nick, 2018, (Stanford Encyclopedia of Philosophy), Zeno's Paradoxes, (accessed 29/9/2019) : available from http://plato.stanford.edu/entries/paradox-zeno/; Internet.

Hussey, E. L. (1995) Parmenides in *The Oxford Companion to Philosophy*, ed. Ted Honderich, Oxford University Press Oxford pp 645-646

Ismael, Jennan, (2000) Quantum Mechanics Stanford Encyclopedia of Philosophy, (accessed 6/5/2008) : url =<http://plato.stanford.edu/entries/qm/>

Jech, Thomas, (1997) *Set Theory,* Springer, Berlin

Joannes-Boyau, Renaud, New Moroccan fossils suggest humans lived and evolved across Africa 100,000 years earlier than we thought, (accessed 8/6/2017) : available from http://theconversation.com/new-moroccan-fossils-suggest-humans-lived-and-evolved-across-africa-100-000-years-earlier-than-we-thought-78826; Internet.

John Paul II (1983), *Code of Canon Law,* (accessed 23/7/2019) : available from http://www.vatican.va/archive/cod-iuris-canonici/cic_index_en.html; Internet.

________ (1996), Address to Plenary Session on 'The Origins and Early Evolution of Life', (accessed 4/6/2019) : available from http://www.pas.va/content/accademia/en/magisterium/johnpaulii/22october1996.html; Internet.

Kant, Immanuel, (1784) What is Enlightenment, (accessed 25/6/2019) : available from http://www.columbia.edu/acis/ets/CCREAD/etscc/kant.html; Internet.

Kauffman, Stuart, (1995) *At Home in the Universe: The Search for Laws of Complexity*, Oxford University Press, Oxford

Kepler, Johannes, and Charles Glenn Wallis (Translator), (1517, 1621, 1995) *Epitome Astronomiae Copernicanae* (3 Volumes) [*The Epitome of Copernican Astronomy and Harmonies of the World*], Prometheus, New York

Khinchin, A. I., (1957) *Mathematical Foundations of Information Theory*, Dover, New York

Kirchoff, Gustav, (1860), Ueber das Verhältniss zwischen dem Emissionsvermögen und dem Absorptionsvermögen der Körper für Wärme und Licht, (accessed 5/6/2019) : available from https://

onlinelibrary.wiley.com/doi/abs/10.1002/andp.18601850205; Internet. [Translated by Guthrie, F. as Kirchhoff, G. (1860). "On the relation between the radiating and absorbing powers of different bodies for light and heat". Philosophical Magazine. Series 4. 20: 1–21.]

Klein, Richard G., (1999) *The Human Career: Human Biological and Cultural Origins,* University of Chicago Press, Chicago

Kraut, Richard (2009) Plato Stanford Encyclopedia of Philosophy, (accessed 12/17/2009) : url = <http://plato.stanford.edu/entries/plato/>

Kuhlmann, Meinard (2006) Quantum Field Theory Stanford Encyclopedia of Philosophy, (accessed 7/9/2010) : url = <http://plato.stanford.edu/entries/quantum-field-theory/>

Kuhn, Thomas S., (1987) *Black-Body Theory and the Quantum Discontinuity 1894-1912,* University of Chicago Press, Chicago and London:

_________, (1962, 1970, 1996) *The Structure of Scientific Revolutions,* U of Chicago Press, Chicago

Kundakovic, Marija and Frances A Champagne, (2015) Early-life experience, epigenetics and the developing brain, (accessed 9/9/2018) : available from http://www.nature.com.proxy.library.adelaide.edu.au/articles/npp2014140; Internet.

Landauer, Rolf, (1996), The physical nature of information, (accessed 8/12/2011) : available from http://qi.ethz.ch/edu/qisemFS09/papers/64_Landauer_The_physical_nature_of_information.pdf; Internet.

Lesher, James, (Stanford Encyclopedia of Philosophy), Xenophanes, (accessed 28/5/2019) : available from http://plato.stanford.edu/entries/xenophanes/; Internet.

Lonergan, Bernard J. F., (1992) *Insight : A Study of Human Understanding* (Collected Works of Bernard Lonergan : Volume 3), University of Toronto Press, Toronto

__________, (1997) *Verbum: Word and Idea in Aquinas* (Collected Works of Bernard Lonergan volume 2), Toronto: University of Toronto Press.

__________, 2007 *The Triune God: Systematics* (Collected Works of Bernard Lonergan volume 12), Toronto: University of Toronto Press

McDonald, Jo, & Megan Berry, Murujuga, Northwestern Australia: When Arid Hunter -Gatherers Became Coastal Foragers , (accessed 8/7/2019) : available from https://www.tandfonline.com/doi/abs/10.1080/15564894.2015.1125971?needAccess=true&journalCode=uica20&; Internet

MacHamer, Peter, (2009) Galileo Galilei Stanford Encyclopedia of Philosophy, (accessed 7/9/2010) : url = <http://plato.stanford.edu/entries/galileo/>

McGrew, W. F., *et. al.,* Atomic clock performance enabling geodesy below the centimetre level, (accessed 30/11/2018) : available from https://www.nature.com/articles/s41586-018-0738-2; Internet.

Maxwell, James Clerk, (1873, 1998) *Treatise on Electricity and Magnetism,* Oxford University Press, Oxford

Migne, Jacques Paul, (1844-82) *Patrologiae cursus completus Series Latina*, (vols 1-221), Paris

__________, (1857-87) *Patrologiae cursus completus Series Graeca,* (vols 1-166), Paris

Misner, Charles W, Kip S Thorne and John Archibald Wheeler, (1973) *Gravitation,* Freeman, San Francisco

NASA, (2012) Wilkinson Microwave Anisotropy Probe (WMAP), (accessed 22/2/2003) : available from http://map.gsfc.nasa.gov/; Internet.

Newton, Isaac, (1729, 1972) *Philosophiae Naturalis Principia Mathematica*, Harvard University Press, Cambridge, Massachusetts, 1972.

________, (1726), General Scholium, (accessed 21/10/2015) : available from http://isaac-newton.org/general-scholium/; Internet.

Nielsen, Michael and Isaac Chuang (2000) *Quantum Computation and Quantum Information,* Cambridge University Press, Cambridge

Nowak, Martin A., Joshua B. Plotkin and Vincent A.A. Jansen (2000) The evolution of syntactic communication, *Nature* 404, 30 March, 495-498.

Orwell, George, In Front of Your Nose, (accessed 17/10/2013) : available from http://orwell.ru/library/articles/nose/english/e_nose; Internet.

Pais, Abraham, (1982) *Subtle is the Lord...: The Science and Life of Albert Einstein*, Oxford University Press, Oxford

Particle Data Group, Lawrence Berkeley National Laboratory, *The Particle Adventure*, (accessed 21/1/2009) : available from http://particleadventure.org/index.html; Internet.

Peacock, John A., (1999) *Cosmological Physics*, Cambridge University Press, Cambridge.

Palmer, John (Stanford Encyclopedia of Philosophy), Parmenides , (accessed 21/3/2019) : available from http://plato.stanford.edu/entries/parmenides/; Internet.

Pinker, Steven, (2011) *The Better Angels of Our Nature: Why Violence Has Declined*, Viking Adult, New York

Planck, Max, (1901) On the Law of Distribution of Energy in the Normal Spectrum, (accessed 2/2/2012) : available from http://theochem.kuchem.kyoto-u.ac.jp/Ando/planck1901.pdf; Internet.

Pope Paul VI (7 December 1965), *Pastoral Constitution on the Church in the Modern World Gaudium et Spes*, (accessed 2/3/2000) : available from http://www.vatican.va/archive/hist_councils/ii_vatican_council/documents/vat-ii_const_19651207_gaudium-et-spes_en.html; Internet.

Planck, Max (1901) On the Law of Distribution of Energy in the Normal Spectrum Annalen der Physik 4: 553 sqq.

Prigogine, Ilya, (1980) *From Being to Becoming: Time and Complexity in the Physical Sciences*, Freeman, San Francisco

Pryke, Louise, Guide to the classics: The Epic of Gilgamesh (8 May 2027), (accessed 3/6/2019) : available from https://theconversation.com/guide-to-the-classics-the-epic-of-gilgamesh-73444; Internet.

Purvis, Andy, A composite estimate of primate phylogeny, (accessed 8/7/2019) : available from https://www.ncbi.nlm.nih.gov/pubmed/7480112; Internet [10.1098/rstb.1995.0078]

Reid, Nick Patrick Nunn & M. Sharpe (2014), Indigenous Australian stories and sea-level change, (accessed 13/7/2019) : available from http://research.usc.edu.au/vital/access/manager/Repository/usc:14264?queryType=vitalDismax&query=indigenous+australian+stories; Internet.

Reynolds, Vernon, and Ralph Tanner, (1995) *The Social Ecology of Religion*, Oxford University Press, Oxford.

Rickless, Samuel, (2015) (Stanford Encyclopedia of Philosophy), Plato's *Parmenides,* (accessed 20/3/2019) : available from https://plato.stanford.edu/entries/plato-parmenides/; Internet.

Ross, Kenneth A., and Charles A. B. Wright, (1992) *Discrete Mathematics*, Prentice Hall, Englewood Cliffs

Russell, Bertrand, (1903, 1938, 1996) *The Principles of Mathematics,* W W Norton & Co New York:

Salart, Daniel, 2008 Testing the speed of 'spooky action at a distance' Nature 454: 861-864.

Seiradakis, J. H. & M .G. Edmunds, (2018) Our current knowledge of the Antikythera Mechanism, (accessed 6/10/2019) : available from https://doi-org.proxy.library.adelaide.edu.au/10.1038/s41550-017-0347-2; Internet.

Shannon, Claude E., (1948) The mathematical theory of communication, Bell System Technical Journal 27: 379-423, 623-656.

________, (1998). Communication in the Presence of Noise. Proceedings of the IEEE 86: 447-457. Reprint of Shannon, Claude

E 1949 Communication in the Presence of Noise Proceedings of the IEEE 37: 10-21.

Shields, Christopher, (2008) Aristotle, (Standford Encyclopedia of Philosophy) (accessed 7/9/2010) : url = <http://plato.stanford.edu/entries/aristotle/>

________, (2016) The Active Mind of <i>De Anima</i> III 5 (Standford Encyclopedia of Philosophy), (accessed 1/5/2016) : available from http://plato.stanford.edu/entries/aristotle-psychology/active-mind.html; Internet.

Smith, George, (2007) Isaac Newton Stanford Encyclopedia of Philosophy, (accessed 7/9/2010) : url = <http://plato.stanford.edu/entries/newton/>

Smith, James T., David Hilbert's Radio Address, (accessed 26/9/2019) : available from https://www.maa.org › press › periodicals › convergence › david-hilberts-r… ; Internet.

Streater, Raymond F. and Arthur S. Wightman, (1964, 2000) *PCT, Spin, Statistics and All That*, Princeton University Press, Princeton

Stringer, Martin D., (1999), Rethinking Animism: Thoughts from the Infancy of our Discipline, (accessed 17/7/2019) : available from https://www.jstor.org/stable/2661147?origin=crossref&seq=1#page_scan_tab_contents; Internet.

Tanenbaum, Andrew S., (1996) *Computer Networks,* Prentice Hall International, Englewood Cliffs, New Jersey

Tarski, Alfred, (1944) The Semantic Conception of Truth and the Foundations of Semantics. Philosophy and Phenomenological Research 4: (3) 341 - 376

Teilhard de Chardin, Pierre, (1980) *The Phenomenon of Man,* Harper Collins, New York

The Holy See, *Catholic Catechism p1, s2, The Credo: Apostles Creed,* (accessed 4/6/2019) : available from http://www.vatican.va/archive/ccc_css/archive/catechism/credo.htm; Internet.

Turing, Alan, (1936) On Computable Numbers, with an application to the *Entscheidungsproblem*. Proceedings of the London Mathematical Society 2: 230-265.

__________, On Computable Numbers, with an application to the *Entscheidungsproblem*, (accessed 31/10/2011) : available from http://www.cs.virginia.edu/~robins/Turing_Paper_1936.pdf; Internet.

van Heijenoort, Jean, (1999) *From Frege to Goedel: A Source Book in Mathematical Logic 1879 - 1931* iUniverse.com, New York

Veltman, Martinus, (1994) *Diagrammatica: The Path to the Feynman Rules,* Cambridge University Press, New York

von Neumann, John, (1983) *Mathematical Foundations of Quantum Mechanics,* Princeton University Press Princeton

Vulgate.org, The Holy Bible In Latin Language With Douay-Rheims English Translation, (accessed 28/5/2019) : available from http://vulgate.org/ot/psalms_83.htm; Internet.

Weinberg, Steven, (2008) *Cosmology*, Oxford University Press, USA, New York

________, (1995) *The Quantum Theory of Fields Volume I: Foundations*, Cambridge University Press, Cambridge.

________, (1993) *The First Three Minutes: a modern view of the origin of the universe*, Basic Books, New York,

Whitehead, Alfred N., and Bertrand Russell, (1910, 1962) *Principia Mathematica* (Cambridge Mathematical Library), Cambridge University Press, Cambridge

Wigner, Eugene, (1960) The Unreasonable Effectiveness of Mathematics in the Natural Sciences, (accessed 1/16/2001) : available from http://www.dartmouth.edu/~matc/MathDrama/reading/Wigner.html; Internet.

Wildberg, Christian, Stanford Encyclopedia of Philosophy, Neoplatonism, (accessed 3/6/2019) : available from https://plato.stanford.edu/entries/neoplatonism/; Internet.

Wilkins, John S., (2018) (Stanford Encyclopedia of Philosophy), Replication and Reproduction, (accessed 3/10/2019) : available from https://plato.stanford.edu/entries/replication/; Internet.

Zee, Anthony (2003) *Quantum Field Theory in a Nutshell*, Princeton University Press, Princeton & Oxford,

Zemansky, Mark W., (1997) *Heat and Thermodynamics,* McGraw-Hill Education, New York

Zurek, Wojciech Hubert, (2007) Quantum origin of quantum jumps: Breaking of unitary symmetry induced by information transfer in the transition from quantum to classical. Physical Review A 76/5: 1-5.