Archives

Contents

Part I

Synthetic Epistemology

Chapter 1

introduction

This monograph presents some constructive ideas about epistemology, about how we can acquire and apply knowledge. Calling these ideas constructive reflects a purpose distinct from descriptive epistemology but falling short of prescriptive epistemology, offering an epistemological synthesis and some analysis of its merits for consideration as a practical way of advancing the acquisition, representation and application of knowledge to the benefit of mankind.

Three concerns motivate me in this matter.

The first is esoteric and technical, and concerns the exploitation of recent developments in mathematical or symbolic logic. These suggest that some of the formal logical systems devised within the last 100 years may be suitable for the representation of knowledge, and that this kind of knowledge can be regarded as foundational and other kinds then built upon that foundation. A particular concern in this matter is the adoption of such

methods of representation provides a means whereby *Artificial Intelligence* can be made reliable within the scope of the methods, which include all manifestations of deductive reasoning.

My second area of interest is in the nature of scientific truth, the status of scientific authority and the idea of scientific *proof*. This falls into two parts. The first part concerns the application of logic to the construction of abstract models of the physical world, and the ways in which such models may be evaluated. The second part concerns the institutions of science and engineering, looking at these from a sceptical point of view and questioning how such scepticisms might be allayed.

My final area of concern is with morality and politics, with the tribal surrender of rationality to ideology and how to limit the social damage which may result.

Of these three areas of concern, the first is one in which I have some straightforward (if somewhat technical) observations to make and am, insofar as I have one, on home territory. Regrettably this may also be the least important and urgent of the three to which I might make a contribution.

In the second two I move progressively further away from any claim to competence, but feel compelled to seek insight nonetheless by the perceived importance of these areas in contemporary society.

Chapter 2

intro2

Knowledge comes in many forms, even in this tiny fragment of the Universe which we might hope to comprehend. In the microcosmos of planet Earth we are only just in a position not only to accumulate knowledge but to consider those forms and the evident progressions in which they appear.

The diversity of knowledge across the universe exceeds human comprehension, but within the limits to which human intelligence has begun to understand there may be reason to believe that the kinds of kmowledge which exist are progressing, and that we are at this "moment" at the cusp of a particularly significant advance. It is the purpose of this monograph to explore the nature amd significance of that special advance.

Epistemology, the philosophical study of knowledge, dates back to the philosophers of ancient Greece, the name derived from the Greek word for knowledge, ἐπιστήμη (episteme).

Declarative or propositional knowledge is the kind of knowledge expressed in or represented by indicative or declarative sentences (those which may be true or false) in the kinds of language natural to human societies. Such languages in their oral forms are probably coeval with homo sapiens, but it is not until much later, after the invention of written language and convenient media, that we could expect any historical record of epistemological thinking. This we find in the ancient Greek philosophers, whose epistemological thinking may have been provoked by the advances they made in turning mathematics into a theoretical discipline by the systematic use of reason, and the failures they experienced in applying those methods more broadly.

Those conflicting experinces of the effectiveness of reason may be attributed to the relationships found between those distinct applications and an idealisation of propositional knowledge which is central to and foundational for the synthesis which I seek in this monograph.

Chapter 3

intro3

The philosopher and historian of ideas, Isaiah Berlin, when seeking to describe the transition from the age of enlightenment to that of romanticism [**?**], put forward an account of three pillars upon which he supposed the entire Western tradition to have then rested, supplemented by a further element which he attributed to enlightenment thought. Without endorsing the possibility that the diversity of thought in the eighteenth century could credibly be captured within such a schematic, I nevertheless find in it a starting point for an analysis of propositional language which serves my purposes in this epistemological synthesis.

Berlin's three pillars were:

1. That all `genuine' questions have answers.

2. That the answers can be known (not clear how or by whom)

3. That the true answers to genuine questions are all logically compatible.

The extra feature added by enlightenment thought was that the answers are to be found by reason (``deductive or inductive as appropriate to the subject matter''), rather than by revelation, tradition, dogma or introspection.

The suggestion that there might have been a long standing concensus along these lines is refuted at every turn by the philosophical controversies which have raged since the time of Thales, between radical sceptics and the `dogmatists' they opposed, later between philosophical tendencies such as rationalism and empiricism, and among innumerous more subtle positions and reconciliations.

Nevertheless, there may be behind Berlin's intuition something fundamental and transformative which comes with and underpins the utility of propositional language and deductive reason. I suggest here that the particular utility of propositional language in enabling the development of human culture and civilisation and in lifting homo sapiens above the subsistence level, comes from its approximation to an ideal around which philosophers have studied the nature of knowledge and the ways in which it might be established.

The signficance of this moment in the history of ideas and of this particular conceptiom of the fundamental issues at stake, for my story, is that it consitutes an important milestone in the development, application and analysis of propositional language leading up

to a major transition in the midst of which we now find ourselves.

3.1 Epistemology

Berlin's three pillars concern knowledge, if known they are knowledge about knowledge, and hence belong to that part of philosophy which has become known as epistemology. The name epistemology was only coined for the philosophical study of knowlege

3.2 A Historical Sketch

Some structure:

- The beginnings of life, DNA: 3 Billion years ago.
  - Cells -> Organisms -> Animals.
  - The central nervous system: 500 Million years ago
  - The evolution of memory.
- Propositional Language: 300,000 years ago
- Quasi Universal Logical Systems: contemporary.

The place where we now find ourselves, from the perspective which I present here, may best be understood if presented as the outcome of an evolutionary

and a historical process. A first step toward describing that process is to mention the major landmarks on the route. Like many things in the evolution of life on earth, progress along this trail seems to have accelerated, substantially and rapidly, so that our landmarks are very far from evenly spaced.

The logical center point around which the narrative hangs is the evolution of propositional or declarative language, the kind of language which is found primarily in indicative sentences of natural languages, whose

While demurring from further analysis of the merits of Berlin's story as an account of enlightennent thought and its transformation by romanticism, related questions concerning the nature and value of propositional language and the use of reason, particularly deductive reason, is central to my synthesis. Though propositional language probably dates back some 300,000 years, it was not until the philosophers of ancient Greece, maybe 3,000 years ago, that its analysis began. The sucesses of systematic deductive reason in Greek mathematics and its dismal failures in most other domains provided a taunting enigma for philosophers seeking to underpin their theories with the authority realised by Axiomatic Geometry.

Chapter 4

intro4

The purpose of this monograph is to present some ideas on knowledge representation and management.

Since it is primarily philosophical in character and is concerned entirely with knowledge, it is natural for me to think of it, and to present it, as epistemology. I also think of it as architectural design, at its earliest and most abstract stages, of certain aspects of knowledge management systems, the structures which such systems manage. It is nevertheless primarily the former, and as such I have titled the monograph `Synthetic Epistemology', which I will expand upon shortly.

A principle aim of the ideas is to secure precision of meaning in the representation of knowledge and confidence in the results of deductive reasoning in the context of a body of such knowledge, for which the maintenance of logical coherence in such bodies will

be considered essential.[i]

Despite this emphasis on precision of meaming, much of the language used in the exposition will be broadly and imprecisely construed, as befits terms which are drawn from natural languages.

Epistemology permeates philosophy, the boundaries between it and other philosophical disciplines is porous, and in epistemology proper we find only those epistemological concerns which are not local to some other branch of philosophy. There are many other parts of philosophy that are vitally concerned with various aspects of theory about knowledge, and into which I am likely to trespass. Among the more important of these are the philosophies of language, logic, mathematics, science and artificial intelligence.

At a time of rapid progress and high expectations in the engineering of artificial intelligence, the relevance of knowledge representation and knowledge manageent to those developments is certainly an important motivator for these ideas. This has not been prominent in the recent major advances, but if not necessarily figuring in the essentials for engineering intelligence, I believe is is desirable (and inevitable) in their application. My sense of the inevitability comes from observation of the history and evolution of knowledge, epistemology and related disciplines over the last three

[i]So called *non-monotonic* reasoning and relevance logics al within the scope but are not foundational, insofar as they have well degined semantics they can be supported in a system based on classical, two-valued, foundations.

billion years, culminating not only in the present successes in engineering intellience, but also in developments in language and logic reevant to the representation of knowledge.

The central features of the ideas presented here are that:

- A single widely distrubed, consistent and geneally accessible repository of knowledge underpinnied by a single abstract representation with a minimal primitive vocabulary, a clearly defined semantics and a sound but strong formal inference system.

- Lingistic pluralism in presenting the underlying representation in forms convenient for a wide variety of users (human and machine) and pusposes.

- Rules for the expansion of the primitive vocabulary in verificably consistent ways by conservative extension, which underpin the effective linguistic pluralism by semantic embedding.

- Heirarchical naming rules which uniquely assign the namings used by different extensions to single authorities.

It is a philosophical contribution to a problem of engineering design, given that engineering has now advanced so far as to design and construct cognitive artifacts, machines that know.

The design of knowledge bases has tradtionally been an important part of research on artificial intelligence, but though the research continues, it has been eclipsed by the achievements of large scale neural net simulations, which achieve their results independently of that research.

Chapter 5

intro5

This monograph presents the most fundamental elements of a positivist philosophical system in the course of articulating a position on knowledge representation.

Throughout the evolution of life on earth, knowledge (broadly conceived) has played an essential role. Knowledge has come in diverse forms which have co-evolved with life itself, beginning with knowledge of protein structures and the biochemistry of life encoded in the genomes of evolving species, continuing with many stages in the evolution of memory in the central nervous systems of animals, and leading to the evolution of culture, enabled by the emergence of oral language in large brained primates[i].

In the latest tiny fragment[ii] of that history (after oral language acquired the persistence of written

[i] genus homo

[ii] about one millionth

forms) we find the efforts of philosophers to understand knowledge (ultimately to be called epistemology), and the emergence of new kinds of knowledge, such as theoretical mathematics and its adoption of elaborate systematic deductive reasoning to confirm conjectures.

From this point onwards, knowledge and the methods used to present, establish and apply it, ceased to be a natural phenomenon guided only by evolutionary imperatives, becoming, in part, the product of human ingenuity, an engineered artifact.

The ideas about knowledge representation presented here are conceived in the context of and as a culmination of this latter phase in the evolution of knowledge; as an almost inevitable but nevertheless synthetic staging point. An intelligible sketch of the proposal and its philosophical underpinnings depends upon an account of the progress achieved during those last 3,000 years.

5.1 Language, Culture and Reason

For this purpose it is first necessary to say something about declarative language, as it had been for perhaps as long as the previous 300,000 years, with the benefit of hindsight.

Fully fledged oral languages first appeared in homo sapiens enabling oral culture and the beginnings of cultural evolution, which was able to progress much faster than the genetic evolution which had previously

prevailed. This began a process of accelerating evolution which continues to this day, fuelled in large part by technological advancements in the ways in which language could be stored and manipulated.

The term proposition is used here for the principle content of indicative sentences in natural language, that which they assert, subject to certain qualifications. The role of an indicative sentence is to carve a space of possibilities into two groups, one in which the sentence is true, and one in which it is false. The affirmation of a sentence or the proposition it expresses is the same as claiming that it is true, hence ruling out all those possibilities which render it false.

5.2 Greek Philosophy

In ancient Greece, the birthplace of theoretical mathematics and the axiomatic method, a conspicuous divide appeared between the successes of deduction in the narrow domain of mathematics, and its limitations elsewhere. Plato's philosophy reflected this divide in his identification of two worlds, that of ideal forms among which the objects of mathematics are found, and that of appearances, the shadowy world accessible only through our unreliable senses illustrated in his allegory of the cave. Only in the former could certain knowledge be attained. Of the latter, mere opinion at best.

Plato's world of ideal forms was not confined to mathematics, and we may read into his account an

attempt to demarcate a sphere for reason extending well beyond mathematics, creating a domain for rationalist philosophy which has persisted ever since but has never in fact attained the status of mathematics in terms of clarity, certitude and reliability.

The difficulties in Plato's position were immediately apparent and the philosophy of Aristotle attempted a more moderate position, providing in demonstrative science a legitimation of empirical knowledge in which results are obtained by (syllogistic) deduction from first principles based on observation.

5.3 Modern Science

5.4 The Rigorisation of Analysis

5.5 Logical Foundations

5.6 Notes

To do:

- make a connection between semantics and deduction
- draw the contrast between reason in mathematics and elsewhere
- mention the grounds for radical scepticism (and the nature of its moderation in empiricism?)

- three stages:
  - ancient Greek rationalism and its moderation
  - modern science
  - rigorisation of analysis
- from science to engineering?

5.7 Introduction (to 2024-10-17)

This monograph presents the most fundamental elements of a positivist philosophical system in the course of articulating a position on knowledge representation.

The advancement of humanity to its present state of prosperity has depended, substantially if not exclusively, on the accumulation of scientific and technological knowledge facilitating the mastery of our environment. Essential to that process has been language, at first oral, then written, continually advancing in scope and precision, recorded in media progressively supporting greater ease, speed and scale of communication and application.

The accumulation of a largely coherent and widely distributed body of applicable knowledge has been possible because of the approximation of declarative language to an ideal upon which the proposed knowledge base structure is founded. It depends upon sufficiently expressive languages, which first appeared with homo sapiens some quarter of a million years

ago, making it possible for knowledge in to be shared, distributed, and preserved across generations in an evolving oral culture. A key feature of propositional language is that it allows both particular facts and general rules to be expressed, and admits the application of such knowledge to new circumstances by deductive inference. Though much language is context sensitive in its expression of propositions, broadly applicable knowledge is expressible in context free ways which allow for its communication through space and time, and facilitate the aggregation and sharing of knowledge.

It is probable that language co-evolved with oral culture rather slowly at first. It was not until much quite recently, within the last 10 thousand years, that persistent written forms of language appeared, leaving a historical trace informing our understanding of the subsequent evolution of language, and admitting culture to extend beyond what could be preserved in brains and communicated orally.

During this early period, almost the entire history of oral language, the use of language would have routinely involved elementary informal deductive inference, an ability inseparable from competence in language. Signs of more elaborate deductive reasoning come with the emergence of arithmetical notations. But more extensive use of reason in attempting to understand the world around us,

Propositional knowledge is that kind of knowledge which is expressed in one or more indicative sentences;

a proposition is that which an indicative sentence expresses. A proposition is a claim about some subject matter which divides the possibilities for that matter into two groups, those in relation to which the proposition holds, or is true, and those for which it is not. These are sometimes known as the `truth conditions' of the proposition, which for most purposes can be identified with the proposition, which in turn gives an account of the meaning of the indicative sentence which expresses the proposition.

The meaning of a sentence may be sensitive to the context in which it is asserted, but this is not the case for propositions, as the term is used here. This sensitivity means that the proposition expressed by the sentence, and the truth conditional account of its meaning, may vary according to the context in which the sentence is asserted. It is generally possible to disambiguate sentences by making these contextual elements explicit, and some sentences lack contextual dependency, for example, those which express general scientific laws.

The position on knowledge representation has the following principle features:

- It addresses only propositional knowledge
- It underpins deductive reasoning in the context of the

suitable to an age in which the impediments to formal working are diminished an ubiquity of artificial

intelligence for its management and humanised presentation.

The problem of knowledge presentation is one which has been important to those seeking to engineer `artificial intelligence', and remains an important area of research with its own annual conference organised by Kr Inc.. A glimpse of knowledge representation from the perspective of Artificial Intelligence may be seen in [**?**], where it is said that "Effective knowledge representation and reasoning methods are a foundational requirement for intelligent machines".

Chapter 6

intro6

6.1 Foundational Philosophy

The central purposes of this monograph are two. The first is to present some ideas about the representation of knowledge, constituting a suggestion as to how this might be done. The second, in the course of explaining and underpinning those ideas, is to present the most fundamental elements of a philosophical system, encompassing epistemology, metaphysics and the philosophies of language and logic. The ideas are to be made intelligible (to such extent as is within my competence) by a skeletal evolutionary history seeking to expose the key features of the system as an almost inevitable outcome of continued evolutionary progression.[i]

[i] Not necessarily progress!

As well as viewing knowledge and epistemology[ii] through an evolutionary lens, I will present evolution itself as substantially epistemic in character, as involved in the aggregation of knowledge (broadly construed), and as itself evolving.

In thinking of evolution as an epistemic phenomenon going back beyond the earthly origins of life and forward, into the proliferation of intelligence across the galaxy, some stretching of our concepts of evolution and knowledge is needed. In this introduction I will first sketch the broad conceptions of evolution, knowledge and epistemology adopted, and then the highlights of that evolutionary trajectory which takes us from the beginnings of life on earth through to our most fundamental contemporary epistemological understandings, upon which the ensuing proposal for knowledge representation is based.

6.2 Evolution

In Charles Darwin's seminal work[**?**] the origin of species is attributed to a process, which we now know as evolution, consisting in descent with modification guided by natural selection. Later refinements of this idea arise primarily from advances in scientific knowledge of the mechanics of inheritance (genetics) and tie the concept more narrowly to the kinds of biological evolution we see here on earth. Despite the focus of those

[ii] The philosophical theory of knowledge.

modern evolutionary syntheses, the idea of evolutionary progression has found a much wider currency, most conspicuously in ideas about cultural change, but also in relation to technology, language and even the cosmos as a whole.

In those broader contexts, to talk of evolution may mean little more than gradual change. I'm looking for a conception intermediate between those two, broader than Darwin's and the modern syntheses (particularly in extending beyond biological evolution), but definite enough to provide a basis for some high level reasoning about evolutionary outcomes. To that end I propose to identify evolution as a progression of changes involving proliferation with variations (of some kind of organisms or entities), whose outcome is primarily determined by the principle that features conducive to most rapid proliferation will ultimately prevail, numerically: proliferators ultimately predominate. That a process is evolutionary in this broad sense may support cautious inferences about evolutionary outcomes, if a general claim can be supported about factors affecting proliferation. Cuation is particularly necessary in concluding what cannot evolve[iii], and arises from the complexity of the ecosystems in which evolution takes place.

To emphasise the breadth of this conception I note that it does not require that there are self-replicating entities of any kind, and is therefore potentially applicable to prebiotic evolution where there is evolving dif-

[iii] E.g. that altruism cannot evolve.

ferential proliferation of progressively more complex molecules eventually leading to the chemistry necessary to support primitive life forms (possibly via prebiotic self-replication).

6.3 Epistemology

Viewed epistemically, evolution may be thought of as a process of aggregation of knowledge about how to proliferate in the available environmental contexts or niches, which are themselves continuously transformed by that evolutionary process, by the differential replication which drives the evolutionary process (and which makes simplistic projections perilous).

For a sense of the evolutionary trends which are important here, we need a broad conception of knowledge, going far beyond the idea that knowledge is come kind of true belief and embracing more of the diversity which the concept of knowledge has in its general use beyond philosophy. Examples of such use include the idea that the genomes of living organisms encode knowledge of how those organisms can be constructed and how the vital processes of life and reproduction proceed. This is a highly persistent form of knowledge which is passed down through generations changing only at the pace of biological evolution. By complete contrast, even the earliest forms of life in various degrees and manners responsive to their immediate environment, sensing aspects of that environment which they can use to improve their success in grow-

ing and replicating. Any such process involves, we might informally claim, obtaining knowledge of those relevant aspects of the environment and responding accordingly, even though the material representation of that knowledge in early life forms will be no more than a fleeting state of a chemical pathway. These two kinds of `knowledge' have very different characteristics, and considering them as falling in the scope of epistemology (which is convenient for the purposes of this monograph) draws into epistemology at least some aspects of the full range of the field of semiotics.

These contexts are not usually stable, the mere fact of one characteristic of some entity or that kind of entity itself becoming more prevalent changes the environment, if in no other way but increasing demand and competition for the resources those entities require to grow and replicate. Over time, a sequence of such modest changes, each advantageous in its time, may effect a substantial transformation not only of its host, but of an entire ecosystem.

In this process there is a tendency to greater complexity in the entities concerned, indeed complexity is demanded for an organism to replicate

This epistemic perspective on evolution demands a broad conception of knowledge, not the singular focus on knowledge as 'justified true belief' credible enough among philosophers to have inspired debate within my lifetime, though the foundational emphasis upon which this monograph is built emphasises the importance in that broad scheme of foundations

closely related to that narrow focus. That broad conception of knowledge encompasses DNA not only as providing exact codings of the structure of the proteins necessary for life, but also less well understand information determining how the organism develops from embryo through childhood, reproductive adulthood into senescence and death.

The genome of each viable biological species carries the information about how to construct an organism capable of surviving in some particular environmental niche long enough to reproduce more or less similar organisms. Cultural evolution aggregates knowledge primarily in language, preserved, transmitted and applied by a variety of technologies themselves the product of cultural evolution.

What is it that is evolving? Many different aspects of life on earth have been evolving over the last four billion years. For my present purposes a very high level perspective will be helpful, and over a timescale of about 6 billion years since the formation of the earth a high level view which connects the whole gamut of evolutionary currents to epistemological considerations is provided by the evolution and proliferation of intelligence. It is now thought to be about 4.54 billion years since the formation of the earth, which is the time-frame for evolution to reach the point at which the evolution of intelligence becomes evolution by intelligent design. Of those 4.54 billion years, maybe one billion were pre-biotic evolution leading to the first living organisms, three and a half billion were

biological evolution, and that 0.04 billion more than enough for the establishment and acceleration of cultural evolution, enabled by the biological evolution of `intelligence' in the large brains of genus homo.

The resulting intelligence transformed culture into an evolutionary phenomenon moving at a radically higher and hyper-exponentially accelerating pace.

It took around 4 billion years of evolution to deliver intelligence in the genus homo, and more or less at the same time language and oral culture. That moment was an important milestone in an accelerating evolutionary process, which took the primary method of evolution from being genetic to being cultural. That cultural evolution has itself accelerated over the past 300,000 years, with milestones like the invention of agriculture and animal husbandry, the building of civilisations, the creation of written language, and the progression in written and other media for the storage, transmission and exploitation of knowledge.

Though what remains of that 5 billion year window is maybe one billion, the hyper-exponential acceleration seen over the long term in evolutionary progress suggests that the progression during that period will be more substantial than over the previous four billion years.

6.4 The Evolution of Language

The purpose of this monograph is to argue the case for a particular kind of foundational knowledge representation, and to support that case within an appropriate foundational philosophical system. The case is presented using an evolutionary account of the origin of this kind of language, extrapolated to suggest that the prevalence of the proposed kind of representation is virtually inevitable as the evolution and proliferation of intelligent systems progresses through its sixth billion years.

The evolution of language was an important discontinuity in our evolutionary history, since the pace of the cultural evolution which it enabled was much more rapid than that of biological evolution or its more pedestrian cultural predecessor, and would accelerate as bodies of cultural knowledge grew. Without language, knowledge of skills can only be passed by showing and observing, or learned afresh from experience. Similarly, without language, knowledge of places and situations and the resources, opportunities, deficiencies or perils they present can only be obtained through personal acquaintance, not shared through culture.

Once language fuelled the evolution of culture, a number of important trends began which ultimately lead to the epistemic insights presented in this monograph. Spoken language progressively accelerated the culutural aggregation of knowledge. At first this progress

would have been very slow. Though it is not known when language first appeared, that language is supported in homo sapiens by innate mental capabilities (and cerebral structures) found in no other living species, suggests that its evolution took place during a period of rapid cerebral growth which came to an enddrew to a close with homo sapiens.

Throughout the quarter million years (or more) since homo sapiens evolved, it is likely that language and culture grew and refined together. Just as in earlier stages of biological evolution, learning to cope with new environments demanded new kinds of perceptual discrimination and motor skills closely integrated with appropriate kinds of memory, later cultural advances demanded new concepts or the refinement of old ones for their collaborative progression and exploitation.

6.5 The Evolution of Language

In this sketch oriented towards the evolution of kmowledge and epistemology, we can divide the progress into two parts, those before and after the appearance of declarative language. There is no established understanding of exactly where this dividing line belongs, but its exact placement is not important to this narrative, so we may think of this as being approximately the point at which homo sapiens appears, perhaps the time at which sufficient capabilities in the brain were realised, at the end of a million years of rapid growth in the brain.

A distinctive characteristic of declarative language is its connection with the concept of truth. It is only with this that the classical conception of knowledge as some kind (the true kind) of belief be comprehended. Before language, the correspondences between neural structures and events could only be judged by their utility in the struggle for survival and reproduction. With the benefit of language, beliefs can be expressed in sentences which have truth conditions, and by assessing compliance in reality we can assign a truth value to them (the question of justification will be considered later).

This transition is not an instantaneous flash at the point that declarative language appears. Of course, such languages must be developed over time, so there is no point. But also, biologists studying the evolution of memory find, notwithstanding my remark about the dependence of `truth' judgements on language, kinds of memory which they designate `semantic', `declarative' or `explicit'. It seems that the kinds of discrimination found in language pre-date their expression in language.

When declarative language appeared, its development was guided by similar evolutionary imperatives as those memtal discriminations which preceded it. which served their various practical purposes, and which language was designed to communicate between individuals, across groups and through populations. For the language to serve that purpose, it needed only to connect sufficiently well with those pragmatic issues,

for which any precision in truth conditions might not at first be required.

It is only because of a particular thread in the subsequent evolution of language that we can discuss its origin in this way, coloured by a later analysis of this kind of language. We may now say, that declarative language, throughout its evolution, may have worked well for the progression of communal knowledge throught the evolution of culture because it approximates (at first perhaps, rather poorly) an ideal which it is only possible to describe with hindsight.

One such attempt is that of the philosopher and historian of ideas, Isaiah Berlin, who in his account of the roots of romanticism speaks of three pillars on which 'the whole western tradition' rested up to the time of the enlightenment. These were:

Chapter 7

intro7

This monograph makes an epistemological point in the context of a narrative about the evolution of intelligence.

The making of that point belongs to what I term synthetic epistemology. The point is, that a particular family of logical systems is a good representation system for knowledge, the general adoption of which would be advantageous, and may even be inevitable. My making of that point, beyond mere description of the system, falls into two main parts, an evolutionary account of its origin and a foundational philosophical kernel providing a context in which the supporting rationale may be undestood.

The `philosophical kernel' is an indivisible whole integrating metaphysics, language, logic and epistemology, motivated by the role it may play in the advancement of mathematics, science, technology and engineering and their use for the benefit of human-

ity and the proliferation of intelligence.

The evolutionary story describes key aspects of that part of the origin of intelligence which began here on Earth a few billion years ago, progressing through this present moment of supposed epistemological insight into a future in which the progeny of earthly intelligent life spreads across the galaxy and beyond. In this story, the past trajectory is intended to inform the readers understanding of how these logical systems arose and their nature, while the present and future trajectories say something about the significance of them in facilitating the advance of intelligence across the galaxy.

The introduction in this chapter to that story addresses two phases of the progress. The biological evolution of life on earth, up to the point at which intelligent life in the form of homo sapiens emerged, marking also the beginning of a period of accelerating cultural evolution which culminates in the realisation of inorganic intelligent systems by a process involving both cultural evolution and collaborative design. The continued evolution of intelligence may then be expected to proceed by design incrementation at a rapid pace. The biological evolution of intelligent primates took around 4 Billion years. Those primates will have designed intelligent artifacts in less than 400,000 years, and collaboration between those artifacts and their biological predecessors will yield progressively more advanced intelligent artifacts at an astounding pace.

The engineering of artifical intelligence has, for most of its history included research on knowledge representation, which has been eclipsed by the use of neural net related techniques storing knowledge in parameters broadly corresponding to the weights associated with synaptic connections between neurons. These place intelligent artifacts on a similar footing to intelligent animals, but do not contribute to the continuous advancements in the languages of logic, mathematics and science which have brought us to the present day, and which may be thought to require continuing development to secure best advantage of the greater intellectual power which intelligent artifacts will deliver.

There are two closely related divisions of the idea of knowledge which are important here. They are, the distinction between knowing that and knowing how, and that beween declarative and procedural knowledge. These two kinds of knowledge seem very distinct. The classical characterisation of knowledge as justified true belief, relates most clearly to declarative knowledge, but the idea of procedural knowledge embraces a much broader range of phenomenon in which some kind of learning process yeilds subsequent behavoural advantage, without depending on claims which might be believed or justified. Procedural knowledge must be assesed not in terms of truth, but rather utility, and in a context where no purpose can be assigned, such as the early evolution of life on earth, in terms of adpative advantage, in terms of its effect of reproductive fitness.

The distinction between procedural and declarative knowledge therefore seems stark, and insofar as one might be thought to superseed the other, one might search for the time and circumstance at which that happened, for which the most plausible candidate might be that point at which oral declarative langage appeared. Closer comsideration suggests that no decisive transition took place, but rather there has been continuous but accelerating evolution progressing a number of significant metrics of which the most important for this discussiom is in the direction of semantic precision. Though what linguists might

The kinds of knowledge which consist in true beliefs depend upon beliefs having truth conditions. Such conditions are normally associated with meaningful notations, since the idea of truth conditions arose (very recently) in the analysis of the meaning of declarative sentences.

So we might expect that declarative knowledge goes back only as far as declarative language, while procedural knowledge goes back as far as behavioural adaptation. Behavioural adaptation goes back to some of the most primitive organisms, and beyond them is found in the process of biological evolution, which may be said to code into the DNA of each species knowledge of proteins advantageous to that species.

Declarative language is much more recent, not known outside the genus homo and probably exclusive to homo sapiens, dating back no more than 300,000 years. Despite that recent origin of those complex

structured expressions which linguists recognise as languages, communications between the individuals of a species date back almost to the beginnings of life on earth, for we see social behaviour even in primitive bacteria, and all social behaviours depend upon some form of communication whereby individuals influence each other, perhaps to share information about sources of nourishment or dangers or to coordinate behaviours which may be mutually beneficial.

The evolutionary trajectory of greatest interest in articulating the merits of the proposed knowledge representation systems has as enpoints first, the very beginnings of life on earth more than 3 Billion years ago, and latterly, in just the last few decads, the articulation of the logical system here proposed.

Within a whisker of abiogenesis, the origin of life, evolution had crafted the genomes of single celled organisms which, for the sake of successful growth and replication, were responsive to their environments and capable of growing and reproducing in their own environmental niches. We may think of the genome as incapsulating knowledge of how to survive and reproduce, but it is hard to see how that genome can be construed as declarative knowledge.

The run up to realising intelligent artifacts involves substantial bodies of scientific and engineering knowledge, much of it built on mathematical models. Though undountedly knowing how plays and important role, declarative knowledge is a crucial ingredient.

Chapter 8

intro8

This monograph makes an epistemological point in the context of a narrative about the evolution of intelligence.

The making of that point belongs to what I term synthetic epistemology. The point is, that a particular family of logical systems is a good representation system for knowledge, the general adoption of which would be advantageous, and may even be inevitable. My making of that point, beyond mere description of the system, falls into two main parts, an evolutionary account of its origin and a foundational philosophical kernel providing a context in which the supporting rationale may be understood.

The `philosophical kernel' is an indivisible whole integrating metaphysics, language, logic and epistemology, motivated by the role it may play in the advancement of mathematics, science, technology and engineering and their use for the benefit of human-

ity and the proliferation of intelligence.

This introductory chapter is intended to present the most intelligible account of the key features of the whole which can be stated in brief.

Philosophically, the work is foundational, and that foundation is a semantic foundation for declarative language and knowledge. It is a family of closely related core languages with identical abstract syntax and minimal vocabulary and deductive system, over which arbitrary broader vocabularies may be constructed by conservative extension, a safe generalisation of introduction by definition (a definition being the assignment of a name to some entity already known to exist). The members of the family of logical system differ only in the size of their smallest models, and the strength of the axiom of infinity which reflects that size in the axioms of the system. Unlike the conservative extensions whereby a rich volcabulary can be introduced, these axioms associated with the ontologically richer systems do carry risk of incoherence, so there is some advantage in cleaving to the earlier systems in the series, and fortunately, practical applications will not demand controversial ontologies.

In calling these foundational, I am claiming that all declarative language can be interpreted in them. For this to be a definite claim, I must of course give a definition of the concept of declarative language, and in doing so we run into problems of regress, both in relation to semantics (and hence truth) and also concerning proof. These problems have no solution which

is absolutely immune to scepticism.

The evolutionary story describes key aspects of that part of the origin of intelligence which began here on Earth a few billion years ago, progressing through this present moment of supposed epistemological insight into a future in which the progeny of earthly intelligent life spreads across the galaxy and beyond. In this story, the past trajectory is intended to inform the readers understanding of how these logical systems arose and their nature, while the present and future trajectories say something about the significance of them in facilitating the further evolution of intelligence and its proliferation across the galaxy.

A useful first division of knowledge in general is into knowing how (procedural knowledge) and knowing that (declarative knowledge). Procedural knowledge may be said to pervade the history of life on earth, being exhibited by all forms of life which surivive and reproduce. It is important in a full picture of how knowledge has evolved and lead us to where we are now. Declarative knowledge is much more recent, and is confined to those kinds of knowledge which are expressible in declarative sentences, which can be stated in a meaningful sentence which expresses a claim on some subject matter which will be true, or false. Declarative knowledge we may therefore expect to have existed only since the kinds of language in which declarative sentences may be expressed, and to depend vitally upon the language being sufficiently well defined, in its meanings, that the truth conditions

of declarative sentences are definite.

Declarative knowledge has been enormously important in securing for humanity its present levels of prosperity. It evolved during or shortly after a million years of rapid growth in the size of hominid brains which plateauxed

Chapter 9

intro9

This monograph is dedicated to the presentation of a well established logical system as providing a universal representation system for knowledge. In the course of explaining the rationale for these ideas, the logical kernel of a foundational philosophical system, within which the ideas can be understood, will be outlined.

In this introductory chapter, some historical background will be introduced, beginning with Isaiah Berlin's ideas about ``the Western Tradition", (as it stood in the Enlightenment) contrasted with Hume's skepticism, reaching back to the origins of that tradition in Plato and Aristotle before considering the origins of declarative language and that thread of its evolution which lead to formal logical foundations for mathematics, their transformation for application in formal verifiation of digital electronics and this repurposing as a substrate for linguistically pluralistic broad spectrum knowledge representation system.

9.1 Berlin on the Western Tradition

In his book on The Roots of Romanticism[**?**] Isaiah Berlin talks about the ``three legs upon which the whole Western tradition rested", before the enlightenment, as follows:

1. All genuine questions can be answered.

   In principle, by someone. Perhaps only God.

2. The answers are knowable.

3. All the answers are compatible (with each other). It is a logical truth, Berlin says, that one true proposition cannot contradict another.

and then, the extra twist added by the Enlightenment:

> That the knowledge is not to be obtained by revelation, tradition, dogma, introspection..., only by the correct use of reason, deductive or inductive as appropriate to the subject matter.
>
> This extends not only to the mathematical and natural sciences, but to all other matters including ethics, aesthetics and politics.

and... that virtue is knowledge.

This is a simple description, not of reality, but of an unattainable ideal, which was to be repudiated by romanticism.

There are two separate kinds of issue which I will raise about this idea. The first is whether this supposed Western Tradition has a factual basis and utility, the second is whether it is a good characterisation of Enlightenment thought. Notwithstanding the reservations which I will present, I consider that there is a core to this which is important, and that the utility of declarative language in advancing human prosperity depends both upon such language approximating a similar ideal and on the evolution of some specialised parts of language (for example the languages of mathematics and quantitative science). This monograph may be seen as an advocacy for pressing forward that evolution exploiting the growing capability of artificial intelligence.

Lets water this down a little. We'll drop the omniscience

****

Though declarative language does not uniformly comply with this ideal, the mere approximation has been crucial to the progression of humanity from mere subsistence to prosperity and increasing mastery over his environment, and in those areas where elaborate deductive reasoning is beneficial, language has evolved to greater precision and methods of reasoning have become more systematic and rigorous.

It will not be expected that all questions have an answer, for it is convenient sometimes to work with entities for which we have only incomplete descriptions, but it is an aspiration that any question definite

enough to be amenable to deductive reasoning, either in its establishment or its application, can be accommodated within the synthesis.

There are now strong reasons to doubt that the answer to any properly formulated question can be discovered and established. In many aspects of the proposed synthesis, absolutes are known to be unrealisable, and it is more important to be confident in the answers which do come than for such answers to be always forthcoming.

That all the answers be compatible is possibly the most crucial requirement in a system intended for extended deductive elaboration, for in default of coherence, no result can be trusted.

Clearly this is an idealisation

9.2 The Philosophy of David Hume

9.3 Logical Foundations

For reasons which have been extensively discussed, there is no single language and logic which can be universal, either as a foundation for meaning or truth, and so the system discussed here is a family of

The central argument falls into two parts. First the claim is made that the logical system is universal foundation for logical truth, that logical truth in any well-defined language can be reduced to logial truth in this system. The system

Then it is argued that logical truths in any well-defined language is reducible to truth in the proposed logical foundation system. Then

It is not primarily concerned with presenting the technical detail of this system, which has been done elsewhere, but rather with arguments explaining and supporting its broader significance and appliocability. than is widely recognised, and in answering certain sceptical arguments which have played a prominent role in analytic philosophy during the last century.

The system

It contains a certain amount of fundamental philosophical thinking, presenting the logical system as foundational and articulating a philosophical kernel around it.

Chapter 10

intro10

There are many factors which have contributed to the accomplishment and prosperity of homo sapiens. One of the more important must surely be the cultural aggregation of increasingly precise knowledge, enabling the development of agriculture and animal husbandry, and the engineering of useful artifacts and congenial habitats.

Knowledge comes in many forms, even in that tiny fragment of the universe which we might hope to comprehend. In the microcosmos of planet Earth we are only just in a position, not only to accumulate knowledge, but to consider those diverse forms and the evident progressions in which they appear.

The diversity of knowledge across the universe exceeds human comprehension, but within the limits to which human intelligence has begun to understand, there may be reason to believe that the kinds of kmowledge which exist are progressing, and that we are now at the

cusp of a particularly significant epistemic advance. It is the purpose of this monograph to explore the nature and significance of that special advance and discuss its potential impact on the ways in which knowledge is gathered, organised and exploited.

Epistemology, the philosophical study of knowledge, dates back to the philosophers of Classical Greece, the name derived from the Greek word for knowledge ἐπιστήμη (epistēmē). This monograph, which I have styled an `epistemological synthesis', is constructively concerned with the nature of knowledge. It constitutes, not an examination of some epistemological fait accomplit, the true nature of knowledge, but rather the engineering of an epistemological desideratum, how we might do well to think of knowledge.

10.1 What is Knowledge

Sometimes philosophers view knowledge from a narrow anthropocentric perspective, epitomised by the controversy over whether knowledge is justified true belief. This particular perspective prioritises the question of what constitutes `justification', and fuels debate about whether knowledge is possible. In its broader usage, in philosophy and beyond, knds of knowledge are more diverse and the usage of the term is malleable. I ordinary usage one may be said to `know' a fact having once been told by a source who, though by no means an authority, is not known to be a fraud. Beyond that, in the most distant reaches of our evolu-

tionary history, the most primitive organisms responding appropriately to an environmental stimulus, might be said to have made use of environmental knowledge acquired through sensory mechanisms.

10.2 What is Knowledge

The usage of the term knowledge in this monograph will be loose and wide ranging. In this introductory discussion,

10.3

Among the many forms which knowledge takes, declarative knowledge, primarily consisting in that kind of knowledge which can be expressed or represented by indicative sentences (or declarative language, for which a definition will be forthcoming), is relatively recent, having its beginnings probably about the same time as anatomically modern homo sapiens.

Such knowledge has characteristics derived from those of declarative language, and which vary widely according to the domain of discourse. In some domains, such as mathematics, it can be extremely precise in meaning, with deductive methods of confirmation which are highly reliable. In others, particularly those reaching into the deepest recesses of the human mind or the highest achievements of art and literature,

may be subjective in character, imprecise in meaning or uncertain as to truth.

Many will hold these latter truths more important than the dry inhuman theories of mathematics, but cultural refinement is a luxury which only those whose material needs are well catered for can enjoy. It is mathematics and science, with their need for precision and certainty, which have served best to fulfill those material needs leaving to spare for culture.

Declarative language, it seems likely, has its origins around about the same time as anatomically modern homo sapiens, at the culmination of a period of rapid growth in the size of the human brain which furnished us with the intellectual pre-eminince we now enjoy, as well as the necessary anatomical features to support the articulartion and comprehenshion of oral language, but the conception of declarative language which we now have is very much more recent and represents an idealisation of the natural languages which appeared then and have evolved since.

Natural languages themselves fall short of that ideal, but the development of mathematics gradually moved language towards the ideal in those domains where precision, objectivity and assurance were most needed, culminating in the deevlopment in the twentieth century of the formal logial systems which provide almost perfect realisations of the ideal as well as the metatheoretic advances permitting the ideal to be fully articulated.

This I do through some foundational ideas about

the representation of knowledge. Calling these ideas foundational is intended to suggest that some small kernel is to be offered in terms of which a fuller diversity of knowledge may be understood.

This includes the nomination of a preferred `foundation system', a precisely defined but informally presented family of logical systems. A full description of this system depends upon an appropriate philosophical context, which is itself foundational in a similar sense, and must therefore be provided in the account, together with counter-arguments to some of the skeptical claims likely to be offered against it.

In addition to these presentations defining and underpinning the suggested epistemic foundations, I hope to provide grounds for belief in the practical importance of adopting some such uniform foundation, and suggest in this historical context in the evolution of intelligence the adoption of such a system (within a generation) is nigh likely.

The ideas are set in the context of an account of our situation at a crucial point in multiple evolutionary progressions contributing to the evolution of intelligence, among which the evolution of knowledge and epistemology feature prominently.

Chapter 11

intro11

Knowledge is a physical phenomeon in which the structure of some physical medium represents information about something else, some other part or aspect of the physical world, or perhaps about abstractions. Often the correspondence is secured by a causal relationship between the two, the state of the representation being causally dependent on the state of the thing represented.

The forms in which knowledge has manifest during the evolution of life on earth are varied, and have evolved along with life itself. We may think of this evolution as falling into three principle phases.

In the first phase, we may think of evolution as accumulating knowleddge of how to build organisms capable of surviving and reproducing in various environmental niches which is encoded in the genomes of the organic species. These organisms exhibit knowledge of how to thrive and procreate. Insofar as the

organisms are able to sense their environment and respond appropriately, we may see, in the sensory-motor pathways which which effect those capabilities, representations of the relevant aspects of the environment, which ultimately effect the necessary response.

11.1

An important distinction between the kinds of knowledge observable in this domain is that between knowing how and knowing that, of which the former has dominated for most of the history of life on earth. Whenever an organism has a capability which contributes to its ability to survice and reproduce, we may say that it knows how to exercise that capability, and that knowledge will be found to have one or more physical realisations. In very primitive organisms, the capability may be genetically endowed, and the knowledge may then be said to lie both in the genetic codes which control the development of the relevant physical characteristics, and in those physical structures which effect the capability. In more advanced organisms, the capability may be learned, and its embodiment might then be seen in the neural structures, neurons and their synaptic connections, which control the relevant behaviours.

The physical realisation of such an adaptive response may itself be processing knowledge, for the history involves increasingly elaborate ways of processing and responding to environmental stimuli, at

each stage of which information about the sensed environment or about how an appropriate response can be marshalled is involved, all of which may be thought to constitute knowledge represented in some way by physical processes within the organism.

In the latter part of the evolutionary history of our ecosphere, knowling how to survive and replicate is supplemented and further enabled by knowing that certain propositions are true, and declarative knowledge begins to supplement the procedural knowledge hitherto dominant. In this description, it seem that declarative knowledge depends upon language, not merely to identify the content of the knowledge, but also as its representation. This might suggest that declarative knowledge is a purely linguistic phenomenon, and is coeval with language in human beings, perhaps even co-evolved with linguistic competence.

It seems however, that the emergence of declarative knowledge was a more gradual and confused business, for as soon as we try to give a clear characterisation of declarative knowledge we find that most language has and still falls well short of the ideal which such a characterisation delineates.

Chapter 12

intro12

This monograph wraps an evolutionary tale around an epistemological synthesis.

The epistemological synthesis is built upon a logical core, first engineered for narrow mathematical purposes (though not without wider ambition), but is here re-purposed as a universal substrate for the representation of knowledge. It is presented as foundational in providing a primitive base for the largest of superstructures, and hence its advocacy is a variant of the much derided philosophical tendency to foundationalism. The philosophy constructed around it here may also be seen as a reversion to the ancient Aristotelian pursuit of first philosophy, the idea that philosophy has a contribution to make which is in some sense prior to and more general than the sciences. In this case, that the aggregation of a single shared body of coherent knowledge about the world we live in is a desirable end and demands an appropriate foundation

for the representation of knowledge which is common to all the sciences (and beyond).

What has evolution to do with this? There are two evolutionary stories which contribute to understanding the nature of the proposed logical foundations and the thesis I present about their importance for the future.

The first is the story which has lead to the emergence of the logical systems in question, which represent, I suggest, a kind of terminus beyond which further developments to such logical foundations are likely to be marginal (though we are just at the beginning of finding the best ways to build on these foundations). This is a long story from which I present just those elements which are most signficant in leading to the supposed foundational terminus.

The second is a tale of how the future may unfold, and the evolutionary imperatives which will ensure that the identified foundational systems will become the dominant paradigm for rhe representation of knowledge.

This is not science, the principal ideas promoted here are not such as are susceptible to conclusive demonstration, and do not present clear opportunities for falsification. Though this kind of criterion for solid scientific truth has an important place in science. Life normally presents us with choices which have to be made on more tenuous grounds. Engineers routinely work with models of the real world which are known to be adequate applicable approximations, such as the

frameword of Newtonian physics now known to be false. Philosophy probes beyond the uncertainties of everyday life into matters less easy to comprehend and susceptible to greater doubts.

The main substance of this monograph is offered as philosophical, as a contribution to epistemology. That epistemology is conceived of as the the foundation of a broader philosophical system, which will be lightly sketched. Though foundational in character, it is only possible to understand and articulate this system in the context of the evolutionary story which has lead to its core components. The projection of that story into the future is an important motivator for the system, and a principle ground for the speculation that proposed system will eventually prevail.

At its most portentous, this is the story of the evolution of intelligence, and will become the story of its proliferation through the cosmos, in consequence of an evolutionary imperative which defies stasis. These exotic and speculative ideas about the future of intelligence have an important role to play in expounding and motivating the epistemological synthesis, but are colourful accessories to the primary purpose of this monograph which is philosophical.

12.1 Sketch of a Sketch

It is my aim to provide in this introduction a most concise sketch of the core elements of this proposal, leaving for the remainder of the monograph to fill in

and fill out that picture.

Here I preview what those core elements are.

- Remarks on the Foundationalism
-

12.2 First Philosophy and Foundations

I am in this monograph seeking to practice, a foundationalist first philosophy. From a lomg evolutionary perspective, I see us as part of an evolutionary trajectory which from the highest level may be seen as the evolution of intelligence and its proleferation across the galaxy and into the cosmos. That whole process consists of and is fuelled by the aggregation of knowledge on a massive and accelerating scale.

Because this is a kind of evolutionary process we can to some extent anticipate how it will go, and since it is reasonable to

First a key point about the foundational nature of this proposal and my to `first philosophy'. This foundationalism, if it be called that, does not rest on absolutes. It does not regard any truth as absolutely certain, any statement completely precise, or any account of semantics absolutely unambiguous. But I will sometimes talk as if that were the case. The precision with which the proposed semantics allows abstract concepts to be defined and truths about those concepts to be established is extraordinary by comparison

with any prior system. Consequently, I will occasionally make (perhaps oxymoronic) qualified claims to absolutes, using words like `quasi'-universal or `practically'-complete. If ever I should fail to include such qualifications to what appear to be absolute claims, then the reader should supply his own pinch of salt.

More directly pertinent to the idea that this is first philosophy are the following divergencies from the methods of first philosophies most famous practitioners.

- It is Aristotle who coined the term `first philosophy'[i] in the volume which was later to be named `Metaphysics'. In this he conceived first philosophy as addressing those matters which were independent of particular sciences, and hence,in some sense prior to and more general than them. The most important of these issues was the nature of substance, the features of all that exists, rather than those particular to the subject matters of the individual sciences. The foundational stance proposed here regards ontology as conventional, most especially abstract ontology, in which abstract entities have just those properties which we ascribe to them, provided onlt that the attributed properties are logically consistent. This doesn't mean that the choice is wholly arbitrary, and we will discuss a very small number of

[i] If anyone can be credited with coining a term in a language yet to be devised

options for abstract ontology in our foundations among which a choice can be made on pragmatic grounds, for the choices do have practical implications.

Despite divergence on exactly what problems should be addressed by first philosophy, the foundationalism here adopted remains very much in the spirit of Aristotle in holding that there are important matters to be addressed by philosophers which are in some sense prior to and providing support for the conduct of the sciences.

- Descartes' `Method of Doubt' is the other best know example of first philosophy. This method consists in doubting everthing that can be doubted, and then progressing from the slender remains by deductive reasoning. Descartes found he could doubt everything but his own existence, and somehow managed on that basis to deduce that there is a god who is constutionally capable of allowing a world in which anything perceived clearly enough could possibly be false.

  To understand the foundationalism presented here and the arguments with which I support it you must first appreciate the distinction between object and metatheory, closely related to that between an object language (one about which we are talking, perhaps defining) and a meta language (the distinct language in which our discussion takes place). It is the object system which

> is the proposed foundation system, and it is our definition which begins with nothing and procedes to the simplest system which can provide an adequate foundation. In doing this, we use a well established meta-language, together with a handful of neologisms necessary to present a small number of novel features or ideas, and some knowledge of the 4 billion years of evolution which has brought us to this point, with very particular attention to the evolution of the language of mathematics and the quite recent reduction of mathematical reasoning to logical foundations. So, this foundational first philosophy is not conducted in a vacuum or on a tabular rasa.

A more positive prior model of foundationlism which has an important place in the history leading to the present synthesis is found in the work of Frege. Frege's foundationalism was directect primarily at Mathematics, but was

The foundationalism advanced here is broadly similar to the logicism which sought to reduce mathematics to logic, and builds upon the technical advances which came with that project, but continued to progress after the core idea fell out of favour. However the scoping is explicitly more broad, the proposed foundations offered as a (quasi-)universal basis for abstract semantics, thereby providing a basis for deductive reasoning about knowledge of all kinds rather than specifically underpinning mathematics.

12.3 What is Knowledge?

Epistemology is the theory of knowledge. Later I will talk about some of the various kinds of epistemology in order to make clear the synthetic epistemology which I am attempting in this monograph, but for this introduction, doing a bit of synthetic epistmology by talking about knowledge will suffice.

In the broad conception of knowledge which concerns me here,[ii] knowledge is a natural phenomenon in which one physical structure carries information about some other aspect of the real world. Often the relationship is underpinned by a causal connetion between the representation and the structure represented which results in the state of the representation reflecting the state of the causing system and therefore conveying information to anyone observing the relationship who understands how that relationship works.

In some cases this causal relationship is very direct and obvious, for example in perception, when a causal chain from the perceived structure mediated by sense organs results in modifications to synaptic weights in the brain of the observer which represents information about the perceived structure. If the perceiving person then writes an account of his experience, we have a very different representation of information about that structure, and a more complex and uncertain causal relationship between the two. This kind of knowledge, in the brain, is known as `explicit', and its appearance

[ii] Which encompasses the whole of semiotics.

in language as 'declarative'. Declarative knowledge, knowing that, may be distinguished from procedural knowledge, knowing how. Its representation, again in synaptic connections and weights, is a physical system which effects a useful behaviour in response to a suitable physical context, which result in some appropriate physical activity. Even where our knowledge may be of how to accomplish some mental gymnastics, the result will at least have some physical representation in the brain, and most likely will be transcribed into some other physical medium.

Having emphasised the physical nature of both the represenatation of knowledge and its subject, I should aknowledge that, increasingly as human civilisation has advanced, important bodies of knowledge are most naturally seen as speaking about non-physical abstract matters. This is a natural consequence of the pragmatics of generalisation, in which patterns applicable to many distinct physical situations are captured without reference to any specific instance of their applicable instances. Naturally, when we, as epistemologists, talk about these phenomenon, the inevitable (desirable and intended) generalisations and abstraction, will tempt us into considering abstractions from the concrete representations and attribute the representation of knowledge to abstract forms. Nothwithstanding that the representation and the subject will not allways be physical, it will be useful in this discussion to speak as they always are so that we can focus the following talk about abstractions on the relation-

ship between representation and subject matter, which I will speak of as `semantics' however distant it might feel from linguistics.

Semantics is the relationship between knowledge and its subject matters, and the existence of some such relationship is the crucial condition for some physical structure to represent or constitute knowledge.

This concern with the representation of knowledge has not been central to most philosophy, which additional criteria about the fidelity of the representation and the grounds for belief in that fidelity (justification) have been central, and have lead to some philosophers regarding that those criteria can never be realised and that knowledge is therefore unattainable, and others to devote considerable time and energy to the refutation of scepticism. This we may think of as a debate about a particularly fastidious conception of knowledge, while usage in the broad sweep of everyday contexts is much more accomodating. In this context, the conception of knowledge as requiring not only faithful representation but conclusive evidence of that fidelity is a narrowing of the scope of knowledge which would be fatal to the kinds of evolutionary argument which I will in the course of this monograph advance for the future preponderance of informations systems built around the representations of knowledge which this epistemological synthesis advances.

It is now time to talk about semantics, the role of abstract ontolgy in precisely describing the semantic relationships between knowledge and its subject mat-

ter, and hence the role of abstract structures in the representation of knowledge.

12.4 Semantics and Abstraction

12.5 The Structure of this Monograph

The epicenter of this epistemological synthesis is the idea of a quasi-universal logical foundation system, and the exposition has three principle aims:

1. To define and explain the term `quasi-universal foundation system'

2. To present a preferred quasi-universal foundation system, together with support for the claim that it is one.

3. To explain how such a system provides a basis for a distributed shared knowledge base which is suitable for use by an inteligence network expanding across the galaxy and beyond.

4. To motivate the proposed foundations through an account of their origin, and a projection of their role into the future, assessing their role in the light of the evolutionary imperatives which will govern which kinds of intelligent systems will predominate as transgalaxic proliferation progresses.

Chapter 13

edk01

This chapter offers a sketch of how abstract semantics arose, the latest stage in an evolutionary process which ran for about 4 Billion years. Though long running, the pace of the development accelerated and semantics does not appear in anything like the form we now make of it until those billions have shrunk to thousands. It would be very difficult to understand how semantics arose, and how it reached the form on which this epistemological synthesis builds, without some appreciation of what preceded it.

Possibly the single most important landmark on that evolutionary journey (after abiogenesis, the evolution of life itself), was the apprearnance of homo sapiens and with him, language, the coming of age of semiotic systems.

The sketch is intended to provide background and motivation for the philosophical kernel which follows, in which a notion of purely abstract logical truth is

described as a foundation for the representation of declarative knowledge in general, for deductive reasoning in the context of any coherent body of declarative knowlede.

The idea of abstract semantics is closely tied to that of declarative language, and a first characterisation of declarative language is a language defined using a truth conditional semantics, or one for which a semantics can be supplied.

Declarative knowledge is a late appearance in the evolution of life on earth, and has only gradually approached the ideal form in which it is defined here, which depends not only on fully fledged languages rather than the semiotic representations which preceded language, but also on a semantic precision which has only been approached much later. For nine tenths of the history of evolution knowledge has been procedural rather than declarative, i.e. it served a purpose in survival and reproduction without posessing objective factual content.

13.1 Sketch

OK, this is about the evolution of semantics.

The contention is that it is driven by the demand for ever nore elaborate and extensive reasoning. This is a fundamental shift away from the traditional evolutionary progressions, in which planning ahead is not supported and each step in an a devlopment must be advantageous independently of what further steps it

might enable.

Biological evolution, in its most elementary form (with near random variation and ``natural"selection) requires each small step to provide adaptive advantage not just the possibility of future advantage.

13.2 Three

For the purpose of this narrative, ``semantics" is what you need to make declarative language definite in meaning and precise. This is also what it takes to underpin deductive reason and ensure the soundness of arbitrarily lengthy and complex deductive chains and in that way to elaborate the behaviour of abstract models of the real world and thus anticipate the behaviour of engineered systems designed for practical purposes.

It is only now (within the last hundred years) that we have become able properly to describe the concept if semantics whose evolution I discuss. It hinges on the idea of a declarative language as one which has sentences for which the truth conditions can be precisely given.

Though I am talking here of a linguistic phenomenon, and the kind of declarative language if concern dates back no more than maybe 300,000 years, the evolutionary story goes back to the beginning of life on earth, and the conception of declarative language at stake was not properly instantiated until the twentieth century.

So the appearance of declarative language along-

side homo sapiens was a rough and ready affair, which nevertheless may be thought to have had its accelerating impact on human well-being because of its tentative approximation to an idea which we can only now articulate.

Likely the first to approach such an articulation were the philosophers of ancient greece, who in their transformation of geometry and arithmetic into theoretical disciplines laid the first outlines of an axiomatic method which permitted deductive reasoning to be both extended and reliable. In that culture Aristotle articulated the elitist conception of philosophy and his demonatrative science as of merit because persued purely for love of knowledge rather than for some more concrete purpose.

Chapter 14

edk02

The evolution of semantics is a slender thread which is pivotal to the epistemological theses which underpin this synthesis.

There are many ways to give structure to the four billion years of evolution here on earth. The largest scale structure of interest here concerns the evolution of intelligence, which has happened (I suggest) twice, in wholly different ways.

The first time it was biological evolution. The Darwinian evolution of species [**?**], which took life on earth from single celled prokaryotes all the way to the species of genus homo, of which more than one may have been `intelligent', but only one now remains, homo sapiens.

Intelligence comes in degrees and varieties. In using the term in a black and white way here I am adopting, for present purposes, the criterion that intelligence `proper' is the ability to engage in collaborative design

and construction sufficiently well to ultimately engineer intelligent artifacts.

The second time, the evolution which created intelligence was cultural, and not very Darwinian, involving intelligent design as a source of variation, and intelligent selection rather than natural selection (we may debate where the rather artificial boundary between the two might lie). This second evolution of intelligence is not quite yet complete, for by my chosen criteria of intelligence, it will only be complete when we have artificial intelligence capable of engineering new generations of intelligence.

This division of evolution into two stages of similar significance bbut very different duration (Billions of years against hundred thousands), is significant from the point of view of semantics, and the evolution of semantics exposes developments which have been crucial to the re-invention of intelligence.

The second phase, in which cultural evolution takes the lead, is enabled by the evolution of oral language, and thenceforth the continuing accelerating evolution of way of representing, communicating, storing and exploiting knowledge which have been effective in part because of their approximation to an ideal which the evolution of semantics has only very recently permitted to be clearly articulated.

Chapter 15

kernel

The word `philosophy' derives from a greek word meaning `love of knowledge', and in the time of Aristotle embraced what were then known as the sciences. The sciences as we now know them are no longer considered part of philosophy. One alternative conception of philosophy has been that of providing an intellectual context or foundation in which the sciences might be conducted. This is related to Aristotle's undertaking in the volume which became known as his metaphysics, describing it as `first philosophy', or `the study of being qua being'. By that he meant the study of those aspects of all that exists (substance) before considering the particular characteristics which qualify something to be addressed under one of the sciences, i.e. those characteristics which are prior to or more general than science in some way.

The term 'first philosophy' has been used more recently by philosophers deprecating approaches to

philosophy predicated upon philosophy having something to say which is relevant to and prior to science. Nevertheless, historically, in the Western tradition which has descended from the philosophy of Classical Greece, once philosophy was distinct from science, it has been common for the theory of knowledge, `epistemology' to be considered its home ground.

Other contenders for that pivotal status in modern philosophy have been:

- Metaphysics, both because of its status in Aristotle's philosophy and because this is a pursuit which can be set apart from empirical science and studied in its own right by deductive rather than empirical methods.

  Perhaps because the ambitions of metaphysicians have often greatly outstripped the capabilities of their tools (pure reason), the idea that philosophers are not concerned with the concrete world so much as with the analysis of language, has resulted in periods in which:

- philosophy of language has seemed to be philosopher's most central concern. Though what philosophers call `ordinary' language is substantially an accident the study demands empirical methods, and perhaps even an unfortunate accident which for the sake of rigour in both philosophy and science we should discard in favour of the logical notations which emerged after the rigorisation of mathematical analysis in the 19th Century, lead-

ing to the conception that philosophy is most fundamentally concerned with

- logical analysis which sometimes means little different to the analysis of ordinary language

I am myself with those who regard philosophy's most vital role in making possible the accumulation of knowledge and its application to the benefit of mankind by sometimes elaborate predictions about the behaviour of the material world mediated by complex deductive reasoning from our shared body of knowledge. Alongside that, I see the practical effectiveness of foundational thinking in elaborating and applying such methods.

The philosophical kernel which I introduce here is foundational in seeking to provide a general concept of, and abstract representation for, knowledge suitable for use in the sciences and elsewhere, a very general way in which knowledge can be represented which is semantically precise and coherent, and the means to engage in extended deductive reasoning in the application of scientific knowledge to the furtherance of human purposes.

The foundations upon which this rests are logical, supporting reasoning in any domain suitable for coherent deduction (arguably, any coherently well-definable domain) upon the general notion of logical truth (as here defined).

Chapter 16

kernel2

The proposed system for the representation of knowledge is foundational, it is a system to which other ways of representing knowledge are reducible in some sense (to be described). It is therefore necessary in its articulation to speak in general of knowledge representation systems and of the idea of reduction relative to which the proposed system may be seen as universal in a broad class of such systems.

Though the proposal is epistemological, its description depends upon metaphysics (particularly, ontology), philosophy of language, and logic, those four aspects of philosophy combining to articulate the most fundamemtal parts of the system.

Foundationalism has been regarded as a failed doctrine by many philosophers for a good while, but this may well be because they consider only a straw man, in which foundational theses always make absolute claims about the most fundamental parts of their sys-

tems. This I will not do, I aknowledge that neither in relation to meaning nor verification can one ever have absolute precision or certainty. One can however, in certain domains which I will present as of particular importance, come closer to those ideals than any practical purpose demands. Foundations accomplish that end, but they do so from a particular philosophical perspective, so technical adequacy will not necessarily by universally convincing.

The foundational problem in relation to both meaning and truth is how to terminate infinite regress in definition or justification, and this may be presented as a choice between finding a foundation which is self-evidently clear and conclusive, or rendering the foundation precise through the use of language ultimately to be defined in terms of it. In this proposal, this choice is rejected in favour of doing both.

The foundational enterprise can be appreciated as the threading of language through the eye of a needle. The whole of complex languages are to be defined in terms of very simple primitives, which are definable using a tiny part of the languages which can then be constructed upon them.

16.1 Epistemological Abstraction

Epistemology has often been in significant measure influenced by the world around us, and the ways in which human beings are built and acquire and deploy knowledge of themselves and the world around them.

It may also be influenced by or intimately concerned with the language with which we talk about knowledge, not least the meaning of the word ``know''.

The approach here, which we may think of as an approach to `abstract epistemology', seeks to minimise the extent to which epistemology reflects such earthly or anthropomorphic influnces. How could such an epistmology arise, what would be the purpose of attempting to construct such an abstract epistemology, and how could it possibly succeed?

This moment in the evolution of intelligence provides a context in which this might be understood. We stand, as I write, at a point at which many of the hallmarks of intelligence in humans are now to be seen in computational artifacts. We are also venturing into synthetic biology which may transform the evolution of biological intelligent systems, and the ambition to send intelligent systems across the solar system and into the star systems beyond is on the ascendent. It is likely that the promulgation of intelligence across the galaxy will ultimately be predominantly of non-biological intelligence, and that even that central core where biological life has penetrated will be populated by species well advanced beyond homo sapiens, growing progressively more distant from earth and homo sapiens. These are among the motivations to consider epistemology in ways which stand back both from human language about knowledge and human ways of acquiring knowledge.

Pure mathematics provides examples of structures,

knowledge of which will surely be universal among intelligence wherever it is found. The natural numbers, those numbers which we use for counting discrete entities, are a simple example. Abstraction to is the business of pure mathematics, in contact with an alien civilisation, it may be the mathematicians who would best suceed in communicating with their alien counterparts.

16.2 Foundational Metaphysics

The abstract foundation for epistemology here envisaged is a story couched in terms of abstract entities. So what are they, and what abstract entities are there?

The distinction between abstract and concrete is not completely clean, since we can construct abstract entities with concrete constituents. We are here concerned with purely abstract entities, and adopt a conventionalist position in relation to such entities. The question what abstract entities there are is therefore to be determined by context, an aspect of context which might (or might not) be fixed by the language. If it were meaningful to speak of there being absolute truths about what abstract entities exists, it would not impact this position, for the utility of chosing a domain of abstract entities for the purpose of constructing an abstract model or for developing a mathematical theory is not dependent on what abstract entities do or do not `really exist'.

Concrete ontology is not far removed from this con-

ventional stance, though the evaluation criteria which is makes sense to apply to concrete ontologies are more stringent. Concrete ontology, we might expect, is primarily of utility in constructing models of the physical world, and may be subject to similar criteria. Though philosophers have debated the validity of inductive reasoning to establish the truth of empirical generalisations, and have proposed alternatives such as continuous search for falsification, it is clear that the utility of a model of the empirical world may persist in the face of good evidence that it is literally false. Newtons theories of motion and gravitation are the clearest examples, where accepted as false they are nevertheless more widely used than the theories which displaced them and are still thought to be `true'.

16.3 Abstract Languages

Chapter 17

kernel3

The philosophical context for the epistemological synthesis presented in this monograph is a foundational philosophy. The kernel of the philosophy provides the foundations upon which the whole is based.

The kernal is epistemological, but its description involves other aspects of philosophy which may also be thought of as fundamental, including metaphysics and the philosophies of language and logic, all of which are involved in providing a description of the most fundamental concept in this philosophical system, that of abstract logical truth.

17.1 Methodological Preliminaries

A foundational approach to some problem domain consists in discovering some smaller and/or simpler domain (the foundation) to which all the problems in

the more complex domain are reducible.

In the classic conception of knowledge, for a true belief to count as knowledge, it must be supported by a conclusive justification. From this it would follow that a foundation to which knowledge is reducible should itself be beyond doubt. This philosophy and the kernel on which it is based, is skeptical of any absolute claims, it does not assume that it is ever possible to assign meaning to language with absolute precision, or that any sentence can be known to be true with absolute certainty.

Fortunately we do not need such absolutes, life goes on without them. Nevertheless, there are very great differences in the precision of language and the certainty with which truth can be ascertained. There are variations from one domain to another, and within a domain the language may evolve to greater expressiveness and precision with the benefit of experience, and the methods for ascertaining truth can often be progressed to increase their reliability and reach. It is intended that the kernel here presented enables the highest standards in these matters to be achieved in certain special domains which provide a base upon which broader domains and kinds of knowledge can build.

This philosophical kernel is primarily concerned with logical foundations, which have now been progressed to very high levels in semantic expressiveness, certainty of proof, and completeness, though in all these absolutes are not to be expected.

Of logical foundations it is often thought that we must chose betweem a system which is not itself defined in terms of or reducible to some other, or else that circularity of definition must be admitted by defining the most simple case in itself or in some more complex system. Since neither of these approaches is wholly satisfactory in itself, but both are likely to contribute to making the system precise and reliable, I advocate doing both.

In case it may be thought that without achieving the relevant absolutes, the purpose of foundational thinking is abrogated, it may be helpful to mention that the approach of mathematics to logical foundations which took place primarily in the 19th Century was not motivated by a desire for absolutes, but rather by the need to make precise mathematical ideas which had become so lacking in clarity that rigorous proof of mathematical properties involving them was no longer possible. The concept in question were those of mathematical analysis which were founded on a conception of number which included the infinitesimally small, an idea which had never been made clear.

17.2 The Structure of the Kernel

When logical foundations for mathematics were first devised, by Frege and Russell, these were logically universalistic, which means that a single logical system was intended to capture logical truth in all domains, even though its primary aim was at first the demon-

stration that mathematics was reducible to and hence a part of logic. When Carnap sought to apply similar foundation systems to empirical science he saw that they were not able to define empirical concepts, and, partly under the inluence of Hilbert, shifted to a more pluralistic conceptions in which each domain of discourse had its own language in which core empitical concepts had their special physical meaning and associated axiomatic characterisation.

This logical kernel reconciles these two positions by providing a purely abstract logical core (with abstract syntax and abstract semantic domains and mappings) which can be augmented by concrete interpretations of both syntax and semantics. In this kernel only the abstract foundations are provided. Subsequently an account will be given of how this abstract foundation supports more concrete representations and applications.

There is a certain amount of complexity in the abstract foundations, the account of which will be structured in the following way:

- First we define the notion of a declarative language.
- Then the concept of logical truth as a certin kind of sentence in a declarative language.
- Next we discuss the general idea of meaning preserving reductions between languages, and the classes of languages which can then bd said to be equally expressive.

17.3 Declarative Language

A declarative language consists of the following:

- Syntax
    1. A set of disjoint syntactic categories, one of which is the category of sentences
    2. a set of syntactic constructors
    3. for each syntactic constructor an arity which is a finite sequence of syntactic categories.
- Semantics
    1. an assignment to each syntactic category of a semantic domain
    2. an assignment to each syntactic constructor of total mapping from the syntatic categories a semantic map matching the arity of the constructor

17.4 Abstract Logical Truth

The conception of logic truth adopted here is essentially similar to that of Rodolf Carnap, for which analytic truth was a psuedonym, and in terms of which logical necessity was also defined. The presentation here is dissimilar to Carnap's, particularly in the way in which linguistic pluralism is addressed, and we may

also say that Carnap's philosophy was not foundational in relation to logical truth This philosophical kernal is devoted to a conception of logical truth. First to its definition, and then to the idea that there could be a practically universal foundation for that notion of logical truth.

By `foundation' in this context I mean, a logical system to which all logical truth is reducible, both in terms of semantics and proof theory, i.e. in defining precise truth conditions for sentences and hence which propositions are true and in determining conclusively which propositions satisfy the definition.

Such a foundation for logical truth also provides, I shall argue later, a foundation for all other declarative language, by providing precise abstract semantics for such languages as a starting point for more concrete meanings. An abstract semantics, determines the logical truths expressible in the language, the relationship of entailment between collections of sentences of the language, and hence the principles of sound deduction in the language. From such an abstract semantics, a concrete meaning may be advanced by describing the intended correspondence between concrete entities and abstractions which represent them in the abstract semantics.

This chapter is concerned with the philosophical aspects of these matters, covering methodological considerations and yielding definitions of core concepts such as logical truth, and of the idea of a practically universal foundation for abstract semantics and logical

truth.

In subsequent chapters there will be more definite descriptions of a preferred practically universal system, and discussions of how empirical knowledge and all other kinds of knowledge in which meanings are sufficiently definite to support deductive reasoning can be built upon the proposed logical foundation.

While talking of `universal' foundations and of the precision of semantics and certainty of proof, I will often qualify claims with `practically', and even where this qualification is elided, it should be understood that absolute claims are not intended. There is no intent to deny the well established technical results which limit semantic definitions and formal deductive systems. One of the principal means for achieving practical universality is by talking of families of languages of increasing expressiveness indexed by cardinality of standard interpretations. To talk about universality it is necessary moreover to give a definite description of the class of systems among which universality is claimed, and of the kind of reduction which is admitted to putatively universal members of the class.

Such definitions inevitably invove specific choices of language, and in that way may fail to yield convincingly absolute universals. It is intended that the specific presentations in relation to which universality is claimed are primarily constraints on the presentation of the systems rather than eliminating important systems which might otherwise serve as counterexamples to the hypothesis of universality.

The monograph is philosophical, and most of the metatheoretic claims made, even though they address formal systems which are intended for exact proofs, are hypotheses rather than established results, and despite my efforts to make these hypothesis exact, they may be inherently philosophical rather than technical in character.

17.5 Methodological Prelimaries

Perhaps the best known example of this genre is found in Descartes' Meditations on First Philosophy [**?**], and so I should mention some of most important ways in which my methods differ from those of Descartes.

Descartes' method begins with systematic doubt encompassing everything which can be doubted, finding at first only one thing beyond doubt, his cogito the inference from doubting to existence. Building on this slender base he constructs his entire philosophy, ultimately claiming that the results of his inferences from clear and distinct ideas are indubitable. Unfortunately, the construction of the philosophy on that slender base may seem to the modern eye quite credulous, casting doubt on the sincerity of his radical scepticism.

The methods adopted here are different.

There are several different aspects of the philosophy which are foundational, and they do not all work in the same way, but there are some common features.

Firstly, I do not pretend that in any aspect of this philosophy I doubt all that can be doubted and be-

gin with an alsmost blank slate. I recognise that this synthesis is the product of 4 billion years of evolution on earth of which the final blip is the contributions of the many great thinkers who have contributed to the advancement of our culture.

Thr foundational ideas proposed are not arrived at by systematic doubt, but after consideration of many aspects of the evolution of life on Earth, the cutural evolution enabled by language, and the advances to the present day in science, mathematics and logic giving us the means to precision of language and certaintly of truth in core domains, finally subject to the demands of formal verification using digital information technology. So, no blank slate.

Beyond the philosophical perspective specific technical proposals are made for the representation of knowledge. The foundational role of this philospphical kernel is to provide a context in which the rationale for and the key propoerties of this technical proposal can be understood. The formal logical foundation systems which are discussed are themselves built from a logical kernel, which is a formal language with defined syntax and semantics.

The terminology used in describing this kernel will fall into three groups. Firstly there are many concepts which are used in ways within their existing accepted usage, in some cases with broader application. Where a special or more precise meaning than is already understood is intended, an informal definition will be given, of an existing term which will be used in a spe-

cial way, or of some neologism. Such terms will shown in a special font at the point of definition, and each point of use will hyperlink (in blue) to that definition (in electronic versions, otherwise it may be found via the index of defined terms).

17.6 Logical Foundations

Let me first mention that I am a realist (in a limited sense). There is a material universe, of which I am a very small part, and this monograph is written in the hope that it may be read by other real people and might contribute to the advancement of human affairs. Knowledge, in general, serves primarily to aid our survival, propserity and proliferation in the material world which we inhabit, even when pursued for its own sake.

Our understanding of that `real'[1]world comes in many forms, and is manifest in many ways, but is always incomplete and imperfect, since our knowledge is mediated by senses of limited acuity, and represented in finite media which may not be capable of capturing the infinite variety and subtlety of reality. These ways of acquiring, representing and applying knowledge are conspicuosly evolving, and in the process becoming more precise, in their content and more effective in their application (at least insofar as best practice is concerned; muddle, obfuscation and misrepresentation multiply at the same time!).

Sometimes we find that novel ways of represent-

ing knowledge encompass and surpass many, perhaps all, previous forms. This has happened quite recently through the invention of digital information processing, and the relentless and rapid progress of the technology to support this kind of information storage, processing and communications, with the effect that quite rapidly all previous repositories of knowledge are being digitised, and much greater volumes of data are collected and stored than ever could have been imagined.

There is a legitimate question as to how much of this data constitues knowledge, particularly given that a good account of its meaning may be hard to find. However, this is not a novel phenomenon, knowledge has not usually come accompanied by an explicit account of the semantics of the language in which it is recorded. It suffices for it to be a good representation, that it does indeed carry information about a discernible subject matter.

17.7 Metaphysics

There may be absolute truths about what exists. But, the representation of knowledge as provided for in this synthesis does not depend upon them.

This position is easier to understand in relation to purely abstract entities, i.e. those abstract entities which have no material constituents and are therefore, by conception, located neither in space nor time, and causally independent of the material world.

Such abstract entities suffice for pure mathematics, which provides essential tools for the formulation of theories about the physical world.

17.7.1 Declarative Language

A declarative language is a way of coding information about some domain of interest using some system of symbols which is called syntax. The relationship between the syntax and the domain it concerns is called semantics.

Languages to some extent prejudice the nature of the domain of interest, for it is difficult to speak of some domain without having names to refer to features of the domain, and these choices to limit the possibilities.

Among the syntactic entities some are the names of objects in the domain of interest,

A foundation system is a kind of generic declarative language. There are two ways of thinking about language, and of defining language.

In describing first order logic, it is usual to speak of a first order language as having a fixed vocabulary, adding further named constants creates a new first order language.

This is not what happens with natural languages, which constantly evolve both in terms of adding new words, and by changes to the meaning of existing words. That does give problems in maintaining logical coherence, avoiding equivocation may become nigh

impossible. So if we want to give precise definitions of semantics and provide reliable (sound) rules of deduction, holding the vocabulary fixed is a good idea. When we come to practical applications its not so attractive.

Programming languages are not associated with a fixed vocabulary. You get a variety of constructs and defined terms which come with the language, but the modus operandum is that the process of writing a program consists in chosing new names and adding them to the vocabulary with their definitions. Formal logical systems designed for practical use are similar.

For the purposes of this monograph minimalistic logical kernels devised to be safely extendable are the order of the day.

17.7.2 What is Logical Truth

In essence it is Carnap's conception of logical truth which is presented here [2](though the presentation is very different, as is the philosophical context in which it is placed). It has a purpose which could not be filled by any of the alternative conceptions of logical truth. Disagreements about terminology (what word to use for a concept) have no impact on the substance of this proposal.

A logical truth is a certain kind of sentence in a declarative language, and its definition depends upon the meaning of the sentence. It is therefore necessary to define the concept of declarative language and its

semantics before we come to a definition of logical truth.

Foundational thinking has to address the problem of foundational regress, the need to underpin a supposed foundation. Foundational thinking is reductionist, it is the thesis that for some kind of knowledge.

17.8 Logical Truth

My aim here is to define a notion of logical truth as that term is to be used in this monograph. This may or may not coincide with the idea of logical truth in any other philosophical treatise, it is not my intention to defend this terminology, or to make any claims about it other then those explicit in this monograph.[3]

A logical truth will be defined as a particular kind of sentence in a declarative language, which as defined here will involve a collection of syntactic entities and a semantic mapping assigning meaning to those entities.

A notion of semantic reduction will then be defined, whereby the sentences of one declarative language are mapped into the sentences of some other declarative language in a way which, in a suitable sense, preserves meaning. Such a notion of reduction determines a partial order on the expressiveness of declarative languages. Whenever language A is reducible to language B, then we may say that language B is at least as expressive as language A. This gives us a partial ordering of declarative languages in terms

of expressiveness, and it is clear from well established insights into semantics that there will be no maximal language in this ordering.

We next consider certain paths in this partial ordering, in which the language syntax is fixed, but the semantics varies in ways which strictly increase the expressiveness of the resulting language, and consider the relationship between such families of declarative languages which is induced by the relationship of semantic reduction. One such family is generated from the syntax of first order set theory with semantics determined by the sets of models complying with ever stronger large cardinal axioms. We argue (but cannot prove) that this family is universal for logical truth.

17.8.1 Language

A language[4] is a way of representing information, knowledge or conjecture about some other thing. The information is represented by entities which we call syntax and the relationship between the syntax and those things about which it carries information is called semantics.

Notes

[1]The quotes here reflect my doubts about whether this qualification is appropriate, since ordinary talk about the world suffices to refer to that reality without the explicit ascription.

[2]This topic has been controversial among philosophers in the twentieth century, particularly because of the identification by

Rudolf Carnap of logical truth with analyticity[**?**, **?**] and the very influential attack by Quine [**?**] on that concept. My own view is that Carnap's choice of terminology was good, and Quine's attack baseless, but it is not my purpose here to argue that case.

[3]The intended conception of logical truth is, however, close to the concepts of logical truth and of analyticity adopted by Rudolf Carnap during an important stage in his philosophical development, that ending soon after the publication of Quine's ``Two Dogmas of Empiricism". After that date both were modified as a result of Quine's critique, without significant change to the substance of Carnap's philosophical beliefs.

His concept of analyticity remained the same in essence, but the presentation was re-organised to give a single definition of analyticity as a property of sentences in a language with a given semantics, rather than a general prescription of how language specific definitions of analyticity might be presented.

As to Logical Truth, Quine's critique was more incisive, since in his account of this idea in Meaning and Necessity[**?**] Carnap had stayed too close to the narrow conception of logical truth found in Wittgenstein's Tractatus Logico-Philosophicus1921[**?**]. His resolution of this problem is found in Meaning Postulates[**?**, **?**], which admits into the determination of logical truth the meanings of all concepts in the language rather than just the `logical' by allowing 'meaning postulates' in the semantic definition which capture the sense of the non-logical concepts.

Thenceforth Carnap's conception of logical truth reflected its accidental identification with the narrow conception in Wittgenstein's Tractatus and is closer to the notion of first-order validity favoured in the growing discipline of mathematical logic. Though conceding the term `logical truth' in that way, he continued to relate the concept of analyticity to logical truth by speaking instead of `logical truth in the wider sense'. See, for example `The Philosophy of Rudolf Carnap' [**?**] III/III/15, p 917.

[4]There are many conceptions of and approaches to the concept of language across and within various academic disciplines. The definition offered here is not offered as better than any other, except hopefully, as a vehicle for the epistemological synthesis

presented here. It is, from the perspective of those many others, a narrow conception of language, which is suitable for the proposed foundational role, as contributing something important to the understanding of a wider variety of epistemological phenomena, particular in relation to the possibility of reasoning with or about reprentations of knowledge.

Chapter 18

kernel5

A kernel, as I use the concept here, is a core which provides essential and fundamental elements upon which a larger system of some kind is built.

This chapter presents a kernel for an epistemological philosophical system. A key feature of this kernel is the definition of a notion of logical truth which is considered foundational for knowledge and epistemology. In preparation for promoting a particular formalisation of that conception of logical truth, I describe an ordering on logical systems according to their expressiveness, relative to which a maximally expressive system will be sought.

In the next chapter I will identify a universal family of logical systems and a logical kernel for that family.

The first, which is the subject of this chapter, is the Kernel or fundamental core of a philosophical system within the Western tradition which is generally considered to have begun with the philosophers of Classical

Greece.

In that early beginning, starting around 600 BC with Thales, and progressing through the so called `pre-socratics' to the great intellectual achievements of Plato and Aristotle, philosophy was the love of knowledge,

The philosophy has a kernel because it is an example of `first philosophy', an idea introduced by Aristotle in his Metaphysics [**?**].

Chapter 19

ftt01

Consideration of the domain in which extended deductive reasoning can be made safe has lead to a focus on purely abstract logical truths. In this chapter I will talk about other important domains of discourse and how logical truths can enable deductive reasoning in those domains.

19.1 Hume's Forks

The triple-trichotomy is and elaboration on a theme fundmnetal to the philosophy of David Hume, who gave a central place to the dstinction which became known as `Hume's Fork'

David Hume was a philosopher of the Scottish Enlightenment. The enlightenment was a period of ascendency in the place of reason in the discussion of human affairs, when science had secured its indepen-

dence from the authority of church and state and had a new confidence in its powers occasioned particularly by the successes of Newtonian physics.

Hume looked upon the philosophical writings of his contemporaries and found in them two principle kinds, an ``easy" kind which appealed to the sentiments of the reader, and a ``hard" kind which trawled deeper and appealed to reason. This latter kind, ``commonly called" metaphysics, was preferred by Hume, but found nevertheless, by him, to be lacking, infested with religious fears and prejudices. Hume's feelings about these aspects of philosophy were not vague misgivings. He had a specific epistemological criterion which he saw these philosophical doctrines as violating.

Hume's project involves an enquiry into the nature of human reason for the purpose of eliminating those parts of metaphysics which go beyond the limits of knowledge, and establishing a new metaphysics on a solid foundation limited to those matters which fall within the scope of human understanding.

David Hume wrote his philosophical *magnum opus*, *A Treatise on Human Nature* [**?**] as a young man. He was disappointed to find his work largely ignored and otherwise misunderstood, and thought perhaps that his presentation had been at fault. To improve matters he wrote a shorter work more tightly focussed on the core messages which he thought of greatest importance. This he called *An Enquiry into Human Understanding* [**?**].

In a central place both logically and physically in this more concise account of his philosophy he says:

> ``ALL the objects of human reason or enquiry may naturally be divided into two kinds, to wit, Relations of Ideas, and Matters of Fact.''

We shall see that Hume is here identifying a single dichotomy which corresponds to all three of the distinctions which here concern us. In his next two paragraphs he expands in turn on the kinds he has thus introduced.

19.1.1 Relations of Ideas

> ``Of the first kind are the sciences of Geometry, Algebra, and Arithmetic; and in short, every affirmation which is either intuitively or demonstratively certain. That the square of the hypotenuse is equal to the square of the two sides, is a proposition which expresses a relation between these figures. That three times five is equal to the half of thirty, expresses a relation between these numbers. Propositions of this kind are discoverable by the mere operation of thought, without dependence on what is anywhere existent in the universe. Though there never were a circle or triangle in nature, the truths demonstrated by

> Euclid would for ever retain their certainty and evidence."

Hume is distinctive here among empiricist philosophers in having a broad conception of the *a priori* (though he does not use that term here), allowing that the whole of mathematics is *a priori* (a concept encapsulated in Hume by the phrase ``discoverable by the mere operation of thought ..."). In this he may be contrasted, for example, with Locke who allowed only certain rather trivial logical truths to be knowable *a priori*. Nevertheless, Hume's conception of the *a priori* remains narrow by comparison with the rationalists, and in particular, as Hume will later emphasize, excludes metaphysics.

19.1.2 Matters of Fact

> ``Matters of fact, which are the second objects of human reason, are not ascertained in the same manner; nor is our evidence of their truth, however great, of a like nature with the foregoing. The contrary of every matter of fact is still possible; because it can never imply a contradiction, and is conceived by the mind with the same facility and distinctness, as if ever so conformable to reality. That the sun will not rise tomorrow is no less intelligible a proposition, and implies no more contradiction than the affirmation, that it will rise. We should in

> vain, therefore, attempt to demonstrate its falsehood. Were it demonstratively false, it would imply a contradiction, and could never be distinctly conceived by the mind."

The evolution of the following three dichotomies is the theme of this chapter, though we will find other related dichotomies which feature in the history.

The terms which I will use to speak of them, in this chapter are:

- analytic/synthetic
- necessary/contingent
- a priori/a posteriori

As I shall use these terms these are divisions of different kinds of entity, by different means. For that reason they cannot be said to be identical, and their extents clearly depend upon exactly how the relevant technical concepts are defined, but with suitable and reasonable definitions, these dichotomies prove to be very closely coupled.

The first is a division of sentences, understood in sufficient context to have a definite meaning, and is a division dependent upon that meaning. Meaning is not an univocal term, it is particularly uncertain in meaning, But in this context the requirement is very specific, only one possible component of meaning is required, which is the truth conditions of the sentence. The truth conditions of a sentence are an assignment

of truth values for he sentence in every possible condition (what is a `condition' depends on the language, for natural languages a condition would include both a state of the world and sufficient context to disambiguate the sentence if its meaning is in any way context sensitive).

The second is a division of *propositions*, which may be understood for present purposes as *meanings* of sentences in context. What a proposition is need not be settled except that it must include, again, truth conditions, the context of any sentence having been settled to determine the proposition which it expresses. Such a proposition is considered necessary if it is true in every relevant circumstance, the range of circumstances having been fixed by the language and constituting the subject matter of the language. The concepts of analyticity and necessity are, by this kind of definition, logically related. A sentence is analytic if once disambiguated by appropriate context, it is seen to exppress a necessary proposition. These exact definitions are not to be found in Hume, and are not philosophically uncontroversial, but are presented here so that we can speak of that position adopted by some later philosophers which Hume may be thought to have anticipated.

The division is made according to whether the proposition expressed must under all circumstances have the same truth value, or whether its truth value varies according to circumstance. In this we are concerned with two particular notions of necessity, those

of logical and of metaphysical necessity, the latter being sometimes taken to be broader than the former. A part of the role of Hume's fork in positivist philosophy is to banish metaphysical necessity insofar as this goes beyond logical necessity.

The third is for our purposes also a division of propositions, on a different basis. It concerns the status of claims or of supposed knowledge of propositions. It is expected that such a claim must in some way be *justified* if we are to accept it, and that the kind of justification required depends upon the proposition to be justified. The justification is a priori if it makes no reference to observations about the state of the world, i.e. to sensory observations or other results obtained on the basis of such evidence. The distinction in this case may be described as an epistemic distinction, since it concerns what kind of justification we may expect for the kind of proposition in question.

The suggested identity between the first two concepts has a pale reflection in relation to this epistemic distinction. In this case we do not assert an identity but rather recomend that an a priori justification be required for necessary propositions, and that an e posteriori justification be required for contingent propositions, thus closely if indirectly coupling the three dichotomies.

19.1.3 The Place of The Fork in Hume's Philosophy

The mere statement of the fork (which we shall see, is not original in Hume) is of lesser significance than the role which it plays in Hume's philosophy, which serves to clarify the distinction at stake and draw out its significance.

Hume's philosophy, like Descartes' comes in two parts of which the first is sceptical in character, and the second constructive. In both cases the sceptical part clears the ground for a new approach to philosophy which is then adopted in the constructive phase.

For our present purposes we are concerned principally With the first sceptical phase of Hume's philosophy, because of the delineation of the scope of deductive reason, and hence of the analytic/synthetic dichotomy which is found in Hume's sceptical arguments. This delineation is baldly stated in Hume's first description of the distinction between ``relations between ideas" and ``matters of fact", for there Hume tells us that no matter of fact is demonstrable.

This bald statement would by itself have little persuasive force if it were not followed up with more detail, even though ultimately this detail does not so much underpin the distinction as depend upon it.

Hume's further discussion begins with the consideration of what matters of fact can be known `beyond the present testimony of our senses or the records of our memory'. The inference beyond this immediate

data is invariable causal, we infer from the sensory impressions or memories to the supposed causes of those impressions. But these are not logical inferences, causal necessity is for Hume no necessity at all (even less the inference from effect to cause). Hume's central thesis that matters of fact are not demonstrable is in this way reduced first to the logical independence of cause and effect, and then to the distinction between deductive (and hence sound) inference and inductive inference (whereby we infer causal regularities and their consequences).

Given that Hume considers all inferences from senses to be based on induction, and sees no validity in causal inference, it follows that from information provided directly to us by the senses nothing further can be deduced which is not simply a restatement, selection or summary of the information itself. Further enlightenment from this sceptical doctrine is primarily the application of this principle to various kinds of knowledge. In the process Hume does a certain amount of

19.2 The Triple Trichotomy

The `triple trichotomy' is a presentation of these extended domains of reasoning as a two dimensional matrix, one dimension associated with the distinct domains, the other with different kinds of characteristics which they posess.

In the above table, abstract semantics for logical truths (which are to be established by deductive proof

	Semantics	Evaluation	Modality
Spiritual	non-natural	propriety	normative
Empirical	concrete	utility	contingent
Logical	abstract	proof	necessary

Table 19.1: The Fundamental Triple Trichotomy

and are necessary rather than contingent, or normative). is shown in the lower left corner as befits concepts which are regarded as foundational to the whole.

I will talk through this table in the sections which follow, working from bottom up and left acrosss.

19.3 Semantics

David Hume's philosophy provides us with a first view of the three domains, through two important distinctions. The first is what later became known as the analytic/synthetic distinction, that described by Hume as `relations between ideas' and `matters of fact'. Because Hume talks of it in terms of subject matter, this is readily understood as a semantic distinction. Hume also considers both those two categories as concerned with what is, rather than what ought to be, and says that these normative claims are not derivable from mere descriptions, one cannot derive an `ought' from an

`is', giving us three distinct categories each logically beyond its predecessors.

So how can the abstract semantics which yields logical truth be foundational for these domains which seem logically beyond it? It is foundational because we can mimic the structure of these extended domains in pure abstractions, and then describe map the abstract ontology onto the concrete entities and the normative concepts.

19.4 Evaluation

In the classical conception of knowledge as justified true belief, we see that to establish something as knowledge we must be able to show conclusively that it is true.

List of Tables

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