**The Beginning of Infinity by David Deutsch**

**Chapter 1- The Reach of Explanations**

**Terminology:**

* Explanation- Statement about what is there, what it does, and how and why.
* Reach- The ability of some explanations to solve problems beyond those that they were created to solve.
* Creativity- The capacity to create new explanations.
* Empiricism- The misconception that we ‘derive’ all our knowledge from sensory experience.
* Theory-laden- There is no such thing as ‘raw’ experience. All our experience of the world comes through layers of conscious and unconscious interpretation.
* Inductivism- The misconception that scientific theories are obtained by generalizing or extrapolating repeated experiences, and that the more often a theory is confirmed by observation the more likely it becomes.
* Induction- The non-existent process of ‘obtaining’ referred to above.
* Principle of induction- The idea that ‘the future will resemble the past’, combined with the misconception that this asserts anything about the future.
* Realism- The misconception that statements cannot be objectively true or false, but can be judged only relative to some cultural or other arbitrary standard.
* Instrumentalism- The misconception that science cannot describe reality, only predict outcomes of observations.
* Justificationism- The misconception that knowledge can be genuine or reliable only if it is justified by some source or criterion.
* Fallibilism- The recognition that there are no authoritative sources of knowledge, nor any reliable means of justifying knowledge as true or probable.
* Background knowledge- Familiar and currently uncontroversial knowledge.
* Rule of thumb- ‘Purely predictive theory’ )theory whose explanatory content is all background knowledge)
* Problem- A problem exists when a conflict between ideas is experienced.
* Good/bad explanation- An explanation that is hard/easy to vary while still accounting for what it purports to account for.
* The Enlightenment- (The beginning of) a way of pursuing knowledge with a tradition of criticism and seeking good explanations instead of reliance on authority.
* Mini-enlightenment- A short-lived tradition of criticism.
* Rational- Attempting to solve problems by seeking good explanations; actively pursuing error-correction by creating criticisms of both existing ideas and new proposals.
* The West- The political, moral, economic and intellectual culture that has been growing around the Enlightenment values of science, reason and freedom.

**Meanings of The Beginning of Infinity encountered in this chapter:**

* The fact that some explanations have reach
* The universal reach of some explanations
* The Enlightenment
* A tradition of criticism
* Conjecture: the origin of all knowledge
* The discovery of how to make progress: science, the scientific revolution, seeking good explanations, and the political principles of the West.
* Fallibilism.

**Summary**:

Appearances are deceptive. Yet we have a great deal of knowledge about vast and unfamiliar reality that causes them, and of the elegant universal laws that govern reality. This knowledge consists of explanations: assertions about what is out there beyond the appearances and how it behaves. For most of the history of our species, we had almost no success in creating such knowledge. Where does it come from? Empiricism said that we derive it from sensory ecoeriences. This is false. The real source of our theories is conjecture and the real source of our knowledge is conjecture alternating with criticism. We create theories by rearranging, combining, altering and adding to existing ideas with the intention of improving upon them. The role of experiment and observation is to choose between existing theories, not to be the source of new ones. We interpret experiences through explanatory theories, but true explanations are not obvious. Fallibilism entails not looking to authorities but instead acknowledging that we may always be mistaken, and trying to correct errors. We do so by seeking good explanations – explanations that are hard to vary in the sense that changing the details would ruin the explanation. This, not experimental testing, was the decisive factor in the scientific revolution, and also in the unique, rapid, sustained progress in other fields that have participated in the Enlightenment. That was a rebellion against authority which, unlike most such rebellions, tried not to seek authoritative justifications for theories, but instead set up a tradition of criticism. Some of the resulting ideas have enormous reach: they explain more than what they were originally designed to. The reach of an explanation is an intrinsic attribute of it, not an assumption that we make about it as empiricism and inductivism claim.

**Chapter 2 – Closer to Reality**

**Summary:**

It may seem strange that scientific instruments bring us closer to reality when in purely physical terms they only ever separate us further from it. But we observe nothing directly anyway. All observation is theory-laden. Likewise, whenever we make an error, it is an error in the explanation of something. That is why appearances can be deceptive, and it is also why we, and our instruments, can correct for that deceptiveness. The growth of knowledge consists of correcting misconceptions in our theories. Edison said that research is one per cent inspiration and ninety-nine perspiration- but that is misleading, because people can apply creativity even to tasks that computers and other machines do uncreatively. So science is not mindless toil for which rare moments of discovery are the compensation: the toil can be creative, and fun, just as the discovery of new explanations is. Now, can this creativity and this fun- continue indefinitely?

**Chapter 3- The Spark**

**Terminology:**

* Person- An entity that can create explanatory knowledge
* Anthropocentric- Centred on humans, or on persons.
* Fundamental or significant phenomena- One that plays a necessary role in the explanation of many phenomena, or whose distinctive features require distinctive explanation in terms of fundamental theories
* Principle of Mediocrity- ‘There is nothing significant about humans.’ [a bad philosophy antithetical to the premise of this book]
* Parochialism- Mistaking appearance for reality, or local regularities for universal laws
* Spaceship Earth- ‘The biosphere is a life-support system for humans.’ [another bad philosophy that is disproved in this book]
* Constructor- A device capable of causing other objects to undergo transformations without undergoing any net change itself
* Universal constructor- A constructor that can cause any raw materials to undergo any physically possible transformation, given the right information

**Meanings of The Beginning of Infinity encountered in this chapter:**

* The fact that everything that is not forbidden by laws of nature is achievable, given the right knowledge. ‘Problems are soluble.’
* The ‘perspiration’ phase can always be automated.
* The knowledge-friendliness of the physical world.
* People are universal constructors.
* The beginning of the open-ended creation of explanations.
* The environments that could create an open-ended stream of knowledge, if suitably primed – i.e. almost all environments
* The fact that new explanations create new problems.

**Summary**:

Both the Principal of Mediocrity and the Spaceship Earth idea are, contrary to their motivations, irreparably parochial and mistaken. From the least parochial perspectives available to us, people are the most significant entities in the cosmic scheme of things. They are not ‘supported’ by their environments but support themselves by creating knowledge. Once they have suitable knowledge (essentially, the knowledge of the Enlightenment), they are capable of sparking unlimited further progress.

Apart from eh thoughts of people, the only process known to be capable of creating knowledge is biological evolution. The knowledge it creates (other than via people) is inherently bounded and parochial. Yet it also has c lose similarities with human knowledge. The similarities and the difference are the subject of the next chapter.

**Chapter 4- Creation**

**Terminology:**

* Evolution (Darwinian): Creation of knowledge through alternating variation and selection.
* Replicator- An entity that contributes causally to its own copying.
* Neo-Darwinian- Darwinism as a theory of replicators, without various misconceptions such as ‘survival of the fittest.’
* Meme- An idea that is a replicator.
* Memeplex- A group of memes that help to cause each other’s replication.
* Spontaneous generation- Formation of organisms from non-living precursors.
* Lamarckism- A mistaken evolutionary theory based on the idea that biological adaptations are improvements acquired by an organism during its lifetime and then inherited by its descendents.
* Fine-tuning- Of the constraints or laws of physics were slightly different, there would be no life.
* Anthropic explanation- ‘It is only in universes that contain intelligent observers that anyone wonders why the phenomenon in question happens.”

**Meanings of ‘The Beginning of Infinity’ Encountered in this Chapter:**

* Evolution.
* More generally, the creation of knowledge.

**Summary:**

The evolution of biological adapatations and the creation of human knowledge share deep simiralites, but also some important differences. The main similarities: genes and ideas are both replicators; knowledge and adaptations are both hard to vary. The main difference: human knowledge can be explanatory and can have great reach; adaptations are never explanatory and rarely have much reach beyond the situations in which they evolved. False explanations of biological evolution have counterparts in flase explanations of the growth of human knowledge. For instance, Lamarckism is the counterpart of inductivism. William Paley’s version of the argument from the design clarified what does or not have the ‘appearance of design’ and hence what cannot be explained as the outcome of chance alone- namelyhard-to-very adaptation to a purpose. The origin of this must be the creation of knowledge. Biological evolution does not optimize benefits to the species, the group the individual or even the gene, but only the ability of the gene to spread through the population. Such benefits can nevertheless happen because of the universality of laws of nature and the reach of some of the knowledge that is created. The ‘fine-tuning’ of the laws or constants of physics has been used as a modern form of the argument from design. For the usual reasons, it is not a good argument for a supernatural cause. But ‘anthropic’ theories that try to account for it as a pure selection effect from an infinite number of different universes are, by themselves, bad explanations too – in part because most logically possible laws are themselves bad explanations.

**Chapter 5- The Reality of Abstractions**

**Terminology:**

* Levels of emergence- Sets of phenomena that can be explained well in terms of each other without analyzing them into their constituent entities such as atoms
* Natural numbers- The whole numbers 1,2,3 and so on.
* Reductionism- The misconception that science must or should always explain things by analyzing them into components (and hence that higher-level explanations cannot be fundamental).
* Holism- The misconception that all significant explanations are of components in terms of wholes rather than vice versa.
* Moral philosophy- Addresses the problems of what sort of life to want.

**Meanings of ‘The Beginning of Infinity’ Encountered in this Chapter:**

* The existence of emergent phenomena, and the fact that they can encode knowledge about other emergent phenomena
* The existence of levels of approximation to true explanations
* The ability to understand explanations.
* The ability of explanations to escape from parochialism by ‘letting our theories die in our place’.

**Summary:**

Reductionism and holism are both mistaken. In reality, explanations do not form a hierarchy with the lowest level being the most fundamental. Rather, explanations at any level of emergence can be fundamental.

Abstract entities are real, and can play a role in causing physical phenomena. Causation is itself such an abstraction.

**Chapter 6- The Jump to Universality**

**Terminology:**

* The jump to universality- The tendency of gradually improving systems to undergo a sudden large increase in functionality, becoming universal in some domain.

**Meanings of ‘The Beginning of Infinity’ Encountered in this Chapter:**

* The existence of universality in many fields
* The jump to universality
* Error-correction in computation
* The fact that people are universal explainers
* The origin of life
* The mysterious universality to which the genetic code jumped

**Summary**:

All knowledge growth is by incremental improvement, but in many fields there comes a point when one of the incremental improvements in a system of knowledge or technology causes a sudden increase in reach, making it a universal system in the relevant domain. In the past, innovators who brought about such a jump to universality had rarely been seeking it, but since the Enlightenment they have been, and universal explanations have been valued both for their own sake and for their usefulness. Because error-correction is essential in processes of potentially unlimited length, the jump to universality only ever happens in digital systems.

**Chapter 7- Artificial Creativity**

**Terminology:**

* Quale (plural qualia)- The subjective aspect of a sensation
* Behaviorism- Instrumentalism applied to psychology. The doctrine that science can (or should) only measure and predict people’s behavior in response to stimuli.

**Summary**:

The field of artificial (general) intelligence has made no progress because there is an unsolved philosophical problem at its heart: we do not understand how creativity works. Once that has been solved, programming it will not be difficult. Even artificial evolution may not have been achieved yet, despite appearances. There the problem is that we do not understand the nature of the universality of the DNA replication system.

**Chapter 8- A Window on Infinity**

**Terminology:**

* One-to-one correspondence – Tallying each memberof one set with each member of another
* Infinite (mathematical)- A set is infinite if it can be placed in a one-to-one correspondence with part of itself
* Infinite (physical) A rather vague concept meaning something like ‘larger than anything that could in principle be encompassed by experience.’
* Countably infinite- Infinite, but small enough to be placed in one-to-one correspondence with the natural numbers
* Measure A method by which a theory gives meaning to proportions and averages of infinite sets of things, such as universes.
* Singularity- A situation in which something physical becomes unboundedly large, while remaining everywhere finite.
* Multiverse- A unified physical entity that contains more than one universe
* Infinite regress- A fallacy in which an argument or explanation depends on a sub-argument of the same form which purport to addresss essentially the same problem as the original argument.
* Computation- A physical process that instantiates the properties of some abstract entity
* Proof- A computation which, given a theory of how the computer on which it runs works, establishes the truth of some abstract proposition.

**Meanings of ‘The Beginning of Infinity’ Encountered in this Chapter:**

* The ending of the ancient aversion to the infinite (and the universal)
* Calculus, Cantor’s theory and other theories of the infinite and the infinitesimal in mathematics.
* The view along the corridor of infinity hotel
* The property of infinite sequences that every element is exceptionally close to the beginning
* The universality of reason
* The infinite reach of some ideas
* The internal structure of a multiverse which gives meaning to an ‘infinity of universes’
* The unpredictability of the content of future knowledge is a necessary condition for the unlimited growth of that knowledge

**Summary:**

We can understand infinity through the infinite reach of some explanations. It makes sense, both in mathematics and in physics. But it has counter-intuitive properties, some of which are illustrated by Hilbert’s thought experiment of the Infinity Hotel. One of them is that, if unlimited progress really is going to happen, not only are we now at almost the very beginning of it, we always shall be. Cantor proved, with his diagonal argument, that there are infinitely many levels of infinity, of which physics uses at most the first one or two: the infinity of the natural numbers and the infinity of the continuum. Where there are infinitely many identical copies of an observer (for instance in multiple universes), probability and proportions do not make sense unless that collection as a whole has a structure subject to laws of physics that give them meaning. A mere infinite sequence of universes, like the rooms in Infinity Hotel, does not have such structure, which means that anthropic reasoning by itself is insufficient to explain the apparent “fine-tuning” of the constants of physics. Proof is a physical process: whether a mathematical proposition is provable or unprovable, decidable or undecidable, depends on the laws of physics, which determine which abstract entities and relationships are modeled by physical objects. Similarly, whether a task or pattern is simple or complex depends on what the laws of physics are.

**Chapter 9- Optimism**

**Terminology:**

* Blind optimism (recklessness, overconfidence)- Proceeding as if one knew that bad outcomes will not happen.
* Blind optimism (precautionary principle)- Avoiding everything not known to be safe.
* The principle of optimism- All evils are caused by insufficient knowledge
* Wealth – The repertoire of physical transformations that one is capable of causing

**Meanings of ‘The Beginning of Infinity’ Encountered in this Chapter:**

* Optimism. (And the end of pessimism).
* Learning how not to fool ourselves.
* Mini-enlightenments like those of Athens and Floernce were potential beginnings of infinity

**Summary**

Optimism (in the snese that I have advocated) is the theory that all failures- all evils are due to insufficient knowlesge. This is the key to the rational philosophy of the unknowalble. It would be contentless if there were fundamental limitations to the thre creation of knowledge, but there are not. It would be false if there were fields – especially philosophical fields such as moraility- in which there were no such things as objective progress. But truth does exist in all those fields, and progress towards it is made by seeking good explanations. Problems are inevitable, because our knowledge will always be infinitely far from complete. Some problems are hard, but it is a mistake to confuse hard problems with problems unlikely ot be solved. Problems are soluble, and each particular evil is a problem that can be solved. An optimistic civilization is open and not afraid to innovate, and is based ontraditions of criticism. Its institutions keep improving, and the most important knowledge that they embody is knowledge of how to detect and elimate errors. There may have been many short-live enlightenments in history. Ours has been uniquely long-lived.

**Chapter 10- A dream of Socrates**

**Chapter 11- The multiverse**

**Terminology:**

* Fungible- Identical in every respect
* The world- the whole of physical reality
* Multiverse- the world, according to quantum theory
* Universe- universes are quasi-autonomous regions of the multiverse
* History- A set of fungible universes, over time. One can also speak of the history of parts of a universe.
* Parallel universe- A somewhat misleading way of referring to the multiverse. Misleading because the universes are not perfectly “parallel” (autonomous), and because the multiverse has mych more structure- especially fungibility, entanglement and the measures of histories.
* Instances- In parts of the multiverse that contain universes, each multiversal object consists approximately of ‘instances’, some identical, some not, one in each of the universes.
* Quantum- The smallest possible change in a discrete physical variable.
* Entanglement- Information in each multiversal object that determines which parts (instances) of it can affect which parts of other multiversal objects
* Decoherence- The process of it becoming infeasible to undo the effect of a wave of differentiation between universes
* Quantum interference- Phenomena caused by non-fingible instances of a mutliversal object becoming fungible.
* Uncertainty principle- (The badly misnamed) implication of quantumtheory that, for any fungible collection of instances of a physical object, some of their attributes must be diverse.
* Quantum computation- Computation in which the flow of information is not confined to a single history

**Summary**

The physical world is a multiverse, and its structure is determined by how information flows in it. In many regions of the multiverse, information flwos in quasi-autonomous streams called histories, one of which we call our ‘univers’. Universes approximately obey the lays of classical (pre-quantum) physics. But we know of the rest of the multivers, and can test the laws of quantum physics, because of the phenomenon of quantum interference. Thus a universe is not an exact but an emergent feature of the multiverse. One of the most unfamiliar and counter-intuitive things about the multiverse is fungiblity. The laws of motion of the multiverse are deterministic, and apparent randomness is due to initially fungible usnatnces of objects becoming different, In quantum physics, variables are typically discrete, and how the change from one value to another is a multiversal process involving interference and fungibility.

**Chapter 12- A Physicist’s History of Bad Philosphy**

**Terminology:**

* Bad Philosophy- Philsophy that actively precents growth of knowledge.
* Interpretation- The xplanatory part of a scientific theory, supposedly distinct from its predictive or instrumental part.
* Copenhagen Interpretation- Niels Bohr’s combination of instrumentalism, anthropocentrism and studied ambiguity, used to avoid understanding quantum theory as about reality
* Positivism- The bad philosophy that everything not ‘derived from observation’ should be eliminated from science.
* Logical Positivism- The bad philosophy that statements not verifiable by observation are meaningless.

**Meanings of “The Beginning of Infinity” encountered in this chapter**

* The rejection of bad philosophy

**Summary**

Before the Enlightenment, bad philosophy was the rule and good philosophy the rare exception. With the Enlightenment came much more good philosophy, but bad philosophybecame much worse, with the descent from empiricism (merely false) to positivism, logical positivism, instrumentalism, Wittgenstein, linguistic philosophy, and the ‘postmodernist’ and related movements.

In science, the main impact of bad philosophy had been through the idea of separating a scientific theory into (explationless predictions and (arbitrary interpretation. This has helped to legitimize dehuman izing explanations of human thought and behavior. In quantum theory, bad philosophy manifested itself mainly as the Copenhagen interpretation and its many variants and as the ‘shut-up-and-calculate’ interpretation. These appealed to doctrines such as logical positivism to justify systematic equivocation and to immunize themselves criticism.

**Chapter 13-Choices**

**Terminology:**

* Representative Government- A system of government in which the composition or opinions of the legislature reflect those of the people.
* Social Choice theory- the study of how the ‘will of society’ can be defined in terms of the wishes of its members, and of what social institutions can cause society to enact its will, thus defined.
* Popper’s criterion- Good political institutions are those that make it as easy as possible to detect whether a ruler or policy is a mistake, and to remove rulers or policies without violence when they are.

**Meanings of “The Beginning of Infinity” encountered in this chapter**

* Choice that involves creating new options rather than weighing esisting ones.
* Political Institutions that meet Popper’s Criterion.

**Summary:**

It is a mistake to conceive of shoice and decision-making as a process of selecting from existing opetions according to a fixed formula. That omits the most important element in decision-making, namely the creation of new options. Good policies are hard to vary, and therefore conflicting policies are discrete and cannot be arbitrarily mixed. Just as rational thinking does not consist of weighing the justifications of rival theories, but of using conjecture and criticism to seek the best explanation, so coalition governments are not a desirable objective of electoral systems. They should be judged by Popper’s criterion of how easy they make it to remove bad rulers and bad policies. That designates the plurality voting system as best in the case of advanced political cultures.

**Chapter 14- Why are Flowers Beautiful?**

**Terminology:**

* Aesthetics- The philosophy of beauty
* Elegance- The beauty of explanations, mathematical formulae and so on.
* Explicit- Expressed in words or symbols
* Inexplicit- Not Explicit
* Implicit- Implied or otherwise contained in other information

**Meanings of “The Beginning of Infinity” encountered in this chapter**

* The fact that elegance is heuristic guide to truth
* The need to create objective knowledge in order to allow different people to communicate

**Summary:**

There are objective truths in aesthetics. The standard argument that there cannot be is a relic of empiricism. Aesthetic truths are linked to factual ones by explanations, and also because artistic problems can emerge from physical facts and situations. The fact that flowers reliably seem beautiful to humans when their designs evolved for an apparently unrelated purpose is evidence that beauty is objective. Those convergent criteria of beauty solve the problem of creating hard-to-forge signals where prior shared knowledge is insufficient to provide them.

**Chapter 15- Evolution of Culture**

**Terminology:**

* Culture – A set of shared ideas that cause their holders to behave alike in some ways
* Rational meme- an idea that relies on the recipients’ critical faculties to cause itself to be replicated
* Anti-rational meme- An idea that relies on disabling the recipeients’ critical faculties to cause itself to be replicated.
* Static culture/society- One whose changes happen on a timescale longer than its member can notice. Such cultures are dominated by anti-rational memes
* Dynamic culture/society – One that is dominated by rational memes

**Meanings of “The Beginning of Infinity” encountered in this chapter**

* Biological evolution was merely a finite preface to the main story of evolution, the unbounded evolution of memes.
* So was the evolution of anti-rational memes in static societies.

**Summary**:

Cultures consist of memes and they evolve. In many ways memes are analogous to genes, but there are also profound differences in the way they evolve. The most important differences are that each meme has to include its own replication mechanism, and that a meme exists alternately in two different physical forms: a mental representation and a behavior. Hence also a meme, unlike a gene, is separately selected, at each replication, for its ability to cause behavior and for the ability of that behavior to cause new recipients to adopt the meme. The holders of memes typically do not know why they are enacting them: we enact the rules of grammar, for instance, much more accurately than we able to state them. There are only two basic strategies of meme replication: to help prospective holders or to disable the holders’ critical faculties. The two types of meme- rational memes and antirational memes- inhibit each other’s replication and the ability of the culture as a whole to propagate itself. Western civilization is in an unstable trasitional period between stable, static societies consisting of anti-rational memes and a stale dynamic society consisting of rational memes. Contrary to conventional wisdom, primitive societies are unimaginably unpleasant to live in. Either they are static, and survive only by extinguishing their members’ creativity and breaking their spirits, or they quickly lose their knowledge and disintegrate, and violence takes ober. Existing accounts of memes fail to recognize the significance of the rational/anti-rational distinction and hence tend to be implicitly anit-meme. This is tantamount to mistaking Western cilvilization for a static society, and its citizens for the crushed, pessimistic victims of memes that the members of static societies are.

**Chapter 16- Evolution of Creativity**

**Terminology:**

* Imitation- Copying behavior. This is different from human meme replication, which copies the knowledge that is causing the behavior.

**Meanings of “The Beginning of Infinity” encountered in this chapter**

* The evolution of creativity.
* The reassignment of creativity from its original function of preserving memes faithfully, to the function of creating new knowledge

**Summary**:

On the face of it,creativity cannot have been useful during the evolution of human, because knowledge was growing much too slowly for the more creative individuals to have had any selective advantage, This is a puzzle. A second puzzle is: how can complex memes even exist, given that brains have no mechanism to download them from other brains? Complex memes do not mandate specific bodily actions, but rules. We can see the actions, but not the rules, so how do we replicate them? We replicate them by creativity. That solves both problems, for replicating memes unchanged is the function for which creativity evolved. And that is why our species exists.

**Chapter 17- Unsustainable**

**Terminology**

* The ascent of man – The beginning of infinity. Moreover, Jacob Bronowski’s The Ascent of Man was one of the inspoirations of this book.
* Sustain- the term has two almost opposite, but often confused, meanings: to provide someone with what they need, and to prevent things from changing.

**Meanings of “The Beginning of Infinity” encountered in this chapter**

* Rejecting (the semblance of) sustainability as an aspiration or as a constraint on planning

**Summary**:

Static societies eventually fail because their characteristic inability to create knowledge rapidly must eventually turn some problem into a catastrophe. Analogies between such societies and the technological civilization of the West today are therefore fallacies. Marx, Engels and Diamond’s “ultimate explanation” of the different histories of different societies is false: history is the history of ideas, not of the mechanical effects of biogeography. Strategies to prevent foreseeable disasters are bound to fail eventually, and cannot even address the unforeseeable. To prepare for those, we need rapid progress in science and technology and as much wealth as possible.

**Chapter 18- The Beginning**

**Compiled Terminology found in the book:**

* Explanation- Statement about what is there, what it does, and how and why.
* Reach- The ability of some explanations to solve problems beyond those that they were created to solve.
* Creativity- The capacity to create new explanations.
* Empiricism- The misconception that we ‘derive’ all our knowledge from sensory experience.
* Theory-laden- There is no such thing as ‘raw’ experience. All our experience of the world comes through layers of conscious and unconscious interpretation.
* Inductivism- The misconception that scientific theories are obtained by generalizing or extrapolating repeated experiences, and that the more often a theory is confirmed by observation the more likely it becomes.
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* Fallibilism- The recognition that there are no authoritative sources of knowledge, nor any reliable means of justifying knowledge as true or probable.
* Background knowledge- Familiar and currently uncontroversial knowledge.
* Rule of thumb- ‘Purely predictive theory’ )theory whose explanatory content is all background knowledge)
* Problem- A problem exists when a conflict between ideas is experienced.
* Good/bad explanation- An explanation that is hard/easy to vary while still accounting for what it purports to account for.
* The Enlightenment- (The beginning of) a way of pursuing knowledge with a tradition of criticism and seeking good explanations instead of reliance on authority.
* Mini-enlightenment- A short-lived tradition of criticism.
* Rational- Attempting to solve problems by seeking good explanations; actively pursuing error-correction by creating criticisms of both existing ideas and new proposals.
* The West- The political, moral, economic and intellectual culture that has been growing around the Enlightenment values of science, reason and freedom.
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* Blind optimism (recklessness, overconfidence)- Proceeding as if one knew that bad outcomes will not happen.
* Blind optimism (precautionary principle)- Avoiding everything not known to be safe.
* The principle of optimism- All evils are caused by insufficient knowledge
* Wealth – The repertoire of physical transformations that one is capable of causing
* Fungible- Identical in every respect
* The world- the whole of physical reality
* Multiverse- the world, according to quantum theory
* Universe- universes are quasi-autonomous regions of the multiverse
* History- A set of fungible universes, over time. One can also speak of the history of parts of a universe.
* Parallel universe- A somewhat misleading way of referring to the multiverse. Misleading because the universes are not perfectly “parallel” (autonomous), and because the multiverse has mych more structure- especially fungibility, entanglement and the measures of histories.
* Instances- In parts of the multiverse that contain universes, each multiversal object consists approximately of ‘instances’, some identical, some not, one in each of the universes.
* Quantum- The smallest possible change in a discrete physical variable.
* Entanglement- Information in each multiversal object that determines which parts (instances) of it can affect which parts of other multiversal objects
* Decoherence- The process of it becoming infeasible to undo the effect of a wave of differentiation between universes
* Quantum interference- Phenomena caused by non-fingible instances of a mutliversal object becoming fungible.
* Uncertainty principle- (The badly misnamed) implication of quantumtheory that, for any fungible collection of instances of a physical object, some of their attributes must be diverse.
* Quantum computation- Computation in which the flow of information is not confined to a single history
* Bad Philosophy- Philsophy that actively precents growth of knowledge.
* Interpretation- The xplanatory part of a scientific theory, supposedly distinct from its predictive or instrumental part.
* Copenhagen Interpretation- Niels Bohr’s combination of instrumentalism, anthropocentrism and studied ambiguity, used to avoid understanding quantum theory as about reality
* Positivism- The bad philosophy that everything not ‘derived from observation’ should be eliminated from science.
* Logical Positivism- The bad philosophy that statements not verifiable by observation are meaningless.
* Representative Government- A system of government in which the composition or opinions of the legislature reflect those of the people.
* Social Choice theory- the study of how the ‘will of society’ can be defined in terms of the wishes of its members, and of what social institutions can cause society to enact its will, thus defined.
* Popper’s criterion- Good political institutions are those that make it as easy as possible to detect whether a ruler or policy is a mistake, and to remove rulers or policies without violence when they are.
* Aesthetics- The philosophy of beauty
* Elegance- The beauty of explanations, mathematical formulae and so on.
* Explicit- Expressed in words or symbols
* Inexplicit- Not Explicit
* Implicit- Implied or otherwise contained in other information
* Culture – A set of shared ideas that cause their holders to behave alike in some ways
* Rational meme- an idea that relies on the recipients’ critical faculties to cause itself to be replicated
* Anti-rational meme- An idea that relies on disabling the recipeients’ critical faculties to cause itself to be replicated.
* Static culture/society- One whose changes happen on a timescale longer than its member can notice. Such cultures are dominated by anti-rational memes
* Dynamic culture/society – One that is dominated by rational memes
* Imitation- Copying behavior. This is different from human meme replication, which copies the knowledge that is causing the behavior.
* The ascent of man – The beginning of infinity. Moreover, Jacob Bronowski’s The Ascent of Man was one of the inspoirations of this book.
* Sustain- the term has two almost opposite, but often confused, meanings: to provide someone with what they need, and to prevent things from changing.

**Compiled Meanings of The Beginning of Infinity:**

* The fact that some explanations have reach
* The universal reach of some explanations
* The Enlightenment
* A tradition of criticism
* Conjecture: the origin of all knowledge
* The discovery of how to make progress: science, the scientific revolution, seeking good explanations, and the political principles of the West.
* Fallibilism.
* Person- An entity that can create explanatory knowledge
* Anthropocentric- Centred on humans, or on persons.
* Fundamental or significant phenomena- One that plays a necessary role in the explanation of many phenomena, or whose distinctive features require distinctive explanation in terms of fundamental theories
* Principle of Mediocrity- ‘There is nothing significant about humans.’ [a bad philosophy antithetical to the premise of this book]
* Parochialism- Mistaking appearance for reality, or local regularities for universal laws
* Spaceship Earth- ‘The biosphere is a life-support system for humans.’ [another bad philosophy that is disproved in this book]
* Constructor- A device capable of causing other objects to undergo transformations without undergoing any net change itself
* Universal constructor- A constructor that can cause any raw materials to undergo any physically possible transformation, given the right information
* Evolution.
* More generally, the creation of knowledge.
* The existence of emergent phenomena, and the fact that they can encode knowledge about other emergent phenomena
* The existence of levels of approximation to true explanations
* The ability to understand explanations.
* The ability of explanations to escape from parochialism by ‘letting our theories die in our place’.
* The existence of universality in many fields
* The jump to universality
* Error-correction in computation
* The fact that people are universal explainers
* The origin of life
* The mysterious universality to which the genetic code jumped
* The ending of the ancient aversion to the infinite (and the universal)
* Calculus, Cantor’s theory and other theories of the infinite and the infinitesimal in mathematics.
* The view along the corridor of infinity hotel
* The property of infinite sequences that every element is exceptionally close to the beginning
* The universality of reason
* The infinite reach of some ideas
* The internal structure of a multiverse which gives meaning to an ‘infinity of universes’
* The unpredictability of the content of future knowledge is a necessary condition for the unlimited growth of that knowledge
* Optimism. (And the end of pessimism).
* Learning how not to fool ourselves.
* Mini-enlightenments like those of Athens and Floernce were potential beginnings of infinity
* The rejection of bad philosophy
* Choice that involves creating new options rather than weighing esisting ones.
* Political Institutions that meet Popper’s Criterion.
* The fact that elegance is heuristic guide to truth
* The need to create objective knowledge in order to allow different people to communicate
* Biological evolution was merely a finite preface to the main story of evolution, the unbounded evolution of memes.
* So was the evolution of anti-rational memes in static societies.
* The evolution of creativity.
* The reassignment of creativity from its original function of preserving memes faithfully, to the function of creating new knowledge
* Rejecting (the semblance of) sustainability as an aspiration or as a constraint on planning

**Compiled Summaries from the entire book**:

Appearances are deceptive. Yet we have a great deal of knowledge about vast and unfamiliar reality that causes them, and of the elegant universal laws that govern reality. This knowledge consists of explanations: assertions about what is out there beyond the appearances and how it behaves. For most of the history of our species, we had almost no success in creating such knowledge. Where does it come from? Empiricism said that we derive it from sensory ecoeriences. This is false. The real source of our theories is conjecture and the real source of our knowledge is conjecture alternating with criticism. We create theories by rearranging, combining, altering and adding to existing ideas with the intention of improving upon them. The role of experiment and observation is to choose between existing theories, not to be the source of new ones. We interpret experiences through explanatory theories, but true explanations are not obvious. Fallibilism entails not looking to authorities but instead acknowledging that we may always be mistaken, and trying to correct errors. We do so by seeking good explanations – explanations that are hard to vary in the sense that changing the details would ruin the explanation. This, not experimental testing, was the decisive factor in the scientific revolution, and also in the unique, rapid, sustained progress in other fields that have participated in the Enlightenment. That was a rebellion against authority which, unlike most such rebellions, tried not to seek authoritative justifications for theories, but instead set up a tradition of criticism. Some of the resulting ideas have enormous reach: they explain more than what they were originally designed to. The reach of an explanation is an intrinsic attribute of it, not an assumption that we make about it as empiricism and inductivism claim.

It may seem strange that scientific instruments bring us closer to reality when in purely physical terms they only ever separate us further from it. But we observe nothing directly anyway. All observation is theory-laden. Likewise, whenever we make an error, it is an error in the explanation of something. That is why appearances can be deceptive, and it is also why we, and our instruments, can correct for that deceptiveness. The growth of knowledge consists of correcting misconceptions in our theories. Edison said that research is one per cent inspiration and ninety-nine perspiration- but that is misleading, because people can apply creativity even to tasks that computers and other machines do uncreatively. So science is not mindless toil for which rare moments of discovery are the compensation: the toil can be creative, and fun, just as the discovery of new explanations is. Now, can this creativity and this fun- continue indefinitely?

Both the Principal of Mediocrity and the Spaceship Earth idea are, contrary to their motivations, irreparably parochial and mistaken. From the least parochial perspectives available to us, people are the most significant entities in the cosmic scheme of things. They are not ‘supported’ by their environments but support themselves by creating knowledge. Once they have suitable knowledge (essentially, the knowledge of the Enlightenment), they are capable of sparking unlimited further progress.

Apart from eh thoughts of people, the only process known to be capable of creating knowledge is biological evolution. The knowledge it creates (other than via people) is inherently bounded and parochial. Yet it also has c lose similarities with human knowledge. The similarities and the difference are the subject of the next chapter.

The evolution of biological adapatations and the creation of human knowledge share deep simiralites, but also some important differences. The main similarities: genes and ideas are both replicators; knowledge and adaptations are both hard to vary. The main difference: human knowledge can be explanatory and can have great reach; adaptations are never explanatory and rarely have much reach beyond the situations in which they evolved. False explanations of biological evolution have counterparts in flase explanations of the growth of human knowledge. For instance, Lamarckism is the counterpart of inductivism. William Paley’s version of the argument from the design clarified what does or not have the ‘appearance of design’ and hence what cannot be explained as the outcome of chance alone- namelyhard-to-very adaptation to a purpose. The origin of this must be the creation of knowledge. Biological evolution does not optimize benefits to the species, the group the individual or even the gene, but only the ability of the gene to spread through the population. Such benefits can nevertheless happen because of the universality of laws of nature and the reach of some of the knowledge that is created. The ‘fine-tuning’ of the laws or constants of physics has been used as a modern form of the argument from design. For the usual reasons, it is not a good argument for a supernatural cause. But ‘anthropic’ theories that try to account for it as a pure selection effect from an infinite number of different universes are, by themselves, bad explanations too – in part because most logically possible laws are themselves bad explanations.

Reductionism and holism are both mistaken. In reality, explanations do not form a hierarchy with the lowest level being the most fundamental. Rather, explanations at any level of emergence can be fundamental.

Abstract entities are real, and can play a role in causing physical phenomena. Causation is itself such an abstraction.

All knowledge growth is by incremental improvement, but in many fields there comes a point when one of the incremental improvements in a system of knowledge or technology causes a sudden increase in reach, making it a universal system in the relevant domain. In the past, innovators who brought about such a jump to universality had rarely been seeking it, but since the Enlightenment they have been, and universal explanations have been valued both for their own sake and for their usefulness. Because error-correction is essential in processes of potentially unlimited length, the jump to universality only ever happens in digital systems.

The field of artificial (general) intelligence has made no progress because there is an unsolved philosophical problem at its heart: we do not understand how creativity works. Once that has been solved, programming it will not be difficult. Even artificial evolution may not have been achieved yet, despite appearances. There the problem is that we do not understand the nature of the universality of the DNA replication system.

We can understand infinity through the infinite reach of some explanations. It makes sense, both in mathematics and in physics. But it has counter-intuitive properties, some of which are illustrated by Hilbert’s thought experiment of the Infinity Hotel. One of them is that, if unlimited progress really is going to happen, not only are we now at almost the very beginning of it, we always shall be. Cantor proved, with his diagonal argument, that there are infinitely many levels of infinity, of which physics uses at most the first one or two: the infinity of the natural numbers and the infinity of the continuum. Where there are infinitely many identical copies of an observer (for instance in multiple universes), probability and proportions do not make sense unless that collection as a whole has a structure subject to laws of physics that give them meaning. A mere infinite sequence of universes, like the rooms in Infinity Hotel, does not have such structure, which means that anthropic reasoning by itself is insufficient to explain the apparent “fine-tuning” of the constants of physics. Proof is a physical process: whether a mathematical proposition is provable or unprovable, decidable or undecidable, depends on the laws of physics, which determine which abstract entities and relationships are modeled by physical objects. Similarly, whether a task or pattern is simple or complex depends on what the laws of physics are.

Optimism (in the snese that I have advocated) is the theory that all failures- all evils are due to insufficient knowlesge. This is the key to the rational philosophy of the unknowalble. It would be contentless if there were fundamental limitations to the thre creation of knowledge, but there are not. It would be false if there were fields – especially philosophical fields such as moraility- in which there were no such things as objective progress. But truth does exist in all those fields, and progress towards it is made by seeking good explanations. Problems are inevitable, because our knowledge will always be infinitely far from complete. Some problems are hard, but it is a mistake to confuse hard problems with problems unlikely ot be solved. Problems are soluble, and each particular evil is a problem that can be solved. An optimistic civilization is open and not afraid to innovate, and is based ontraditions of criticism. Its institutions keep improving, and the most important knowledge that they embody is knowledge of how to detect and elimate errors. There may have been many short-live enlightenments in history. Ours has been uniquely long-lived.

The physical world is a multiverse, and its structure is determined by how information flows in it. In many regions of the multiverse, information flwos in quasi-autonomous streams called histories, one of which we call our ‘univers’. Universes approximately obey the lays of classical (pre-quantum) physics. But we know of the rest of the multivers, and can test the laws of quantum physics, because of the phenomenon of quantum interference. Thus a universe is not an exact but an emergent feature of the multiverse. One of the most unfamiliar and counter-intuitive things about the multiverse is fungiblity. The laws of motion of the multiverse are deterministic, and apparent randomness is due to initially fungible usnatnces of objects becoming different, In quantum physics, variables are typically discrete, and how the change from one value to another is a multiversal process involving interference and fungibility.

Before the Enlightenment, bad philosophy was the rule and good philosophy the rare exception. With the Enlightenment came much more good philosophy, but bad philosophybecame much worse, with the descent from empiricism (merely false) to positivism, logical positivism, instrumentalism, Wittgenstein, linguistic philosophy, and the ‘postmodernist’ and related movements.

In science, the main impact of bad philosophy had been through the idea of separating a scientific theory into (explationless predictions and (arbitrary interpretation. This has helped to legitimize dehuman izing explanations of human thought and behavior. In quantum theory, bad philosophy manifested itself mainly as the Copenhagen interpretation and its many variants and as the ‘shut-up-and-calculate’ interpretation. These appealed to doctrines such as logical positivism to justify systematic equivocation and to immunize themselves criticism.

It is a mistake to conceive of shoice and decision-making as a process of selecting from existing opetions according to a fixed formula. That omits the most important element in decision-making, namely the creation of new options. Good policies are hard to vary, and therefore conflicting policies are discrete and cannot be arbitrarily mixed. Just as rational thinking does not consist of weighing the justifications of rival theories, but of using conjecture and criticism to seek the best explanation, so coalition governments are not a desirable objective of electoral systems. They should be judged by Popper’s criterion of how easy they make it to remove bad rulers and bad policies. That designates the plurality voting system as best in the case of advanced political cultures.

There are objective truths in aesthetics. The standard argument that there cannot be is a relic of empiricism. Aesthetic truths are linked to factual ones by explanations, and also because artistic problems can emerge from physical facts and situations. The fact that flowers reliably seem beautiful to humans when their designs evolved for an apparently unrelated purpose is evidence that beauty is objective. Those convergent criteria of beauty solve the problem of creating hard-to-forge signals where prior shared knowledge is insufficient to provide them.

Cultures consist of memes and they evolve. In many ways memes are analogous to genes, but there are also profound differences in the way they evolve. The most important differences are that each meme has to include its own replication mechanism, and that a meme exists alternately in two different physical forms: a mental representation and a behavior. Hence also a meme, unlike a gene, is separately selected, at each replication, for its ability to cause behavior and for the ability of that behavior to cause new recipients to adopt the meme. The holders of memes typically do not know why they are enacting them: we enact the rules of grammar, for instance, much more accurately than we able to state them. There are only two basic strategies of meme replication: to help prospective holders or to disable the holders’ critical faculties. The two types of meme- rational memes and antirational memes- inhibit each other’s replication and the ability of the culture as a whole to propagate itself. Western civilization is in an unstable trasitional period between stable, static societies consisting of anti-rational memes and a stale dynamic society consisting of rational memes. Contrary to conventional wisdom, primitive societies are unimaginably unpleasant to live in. Either they are static, and survive only by extinguishing their members’ creativity and breaking their spirits, or they quickly lose their knowledge and disintegrate, and violence takes ober. Existing accounts of memes fail to recognize the significance of the rational/anti-rational distinction and hence tend to be implicitly anit-meme. This is tantamount to mistaking Western cilvilization for a static society, and its citizens for the crushed, pessimistic victims of memes that the members of static societies are.

On the face of it,creativity cannot have been useful during the evolution of human, because knowledge was growing much too slowly for the more creative individuals to have had any selective advantage, This is a puzzle. A second puzzle is: how can complex memes even exist, given that brains have no mechanism to download them from other brains? Complex memes do not mandate specific bodily actions, but rules. We can see the actions, but not the rules, so how do we replicate them? We replicate them by creativity. That solves both problems, for replicating memes unchanged is the function for which creativity evolved. And that is why our species exists.

Static societies eventually fail because their characteristic inability to create knowledge rapidly must eventually turn some problem into a catastrophe. Analogies between such societies and the technological civilization of the West today are therefore fallacies. Marx, Engels and Diamond’s “ultimate explanation” of the different histories of different societies is false: history is the history of ideas, not of the mechanical effects of biogeography. Strategies to prevent foreseeable disasters are bound to fail eventually, and cannot even address the unforeseeable. To prepare for those, we need rapid progress in science and technology and as much wealth as possible.