CONSCIOUSNESS

GAMES AND SUCH MATTERS

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Anjan Kr Dasgupta

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उत्तिष्ठत जाग्रत प्राप्य वरान्निबोधत |

क्षुरस्य धारा निशिता दुरत्यया दुर्गं पथस्तत् कवयो वदन्ति ||

(Kaṭha Upaniṣad 1/3/14)

Dedication

To my mother,

Late Smt. Bandana Dasgupta,

whose love and sacrifices have been the foundation of everything I've achieved.

Maa, your unwavering belief in perseverance and boundless curiosity about the world around us, both present and past, have been my greatest sources of inspiration.

This quote, your favorite, reflects the spirit of your life.

I feel blessed that the cover page of this book was prepared by you at the age of ninety-four, just before you witnessed your final sunset.

Welcome

> I regard Consciousness as fundamental. I regard matter as derivative from Consciousness. We cannot get behind Consciousness. Everything that we talk about, everything that we regard as existing, postulates Consciousness
>
> Max Planck

Let us start with a personal note. It is too personal to be discussed publicly. Let us be very brief. But I must first mention Suresh Jois, the source of inspiration for this book. An email from Suresh Jois touched me deeply. Like him, long back, I also lost a daughter. I still remember his suffering. I quote an email that he sent me when his daughter was critical, and he left his lucrative US career and dedicated his life so that he could work towards minimizing the suffering of his daughter. He could not save her, but the neural disease's strangeness drew his attention to the strange spectrum of consciousness. The spectral window contains perhaps a narrow slit which we call normal. But this longing to dip into a new world coincided with something else.

Suresh was ahead of his time. In India, he had worked with pioneers of Indian high-performance computing, radio astronomy. He had founded a company that applied cutting edge technologies like 3D modeling and statistical learning (now called ML) to health care, sports performance biochemistry, apparel design etc. In the US he had worked for the world's earliest pioneering companies that created modern web technologies like the browser, E-commerce etc. The ideas in the book were inspired by a casual discussion during a walk on a not-so-crowded road in Bangalore around 2014 when his daughter was no more.

Note

There are moments when people tend to concentrate on the other world. We were doing that. We were discussing the "Grand Challenges" in various subjects. In physics, there is a well-defined set of grand challenges. Suresh was inclined to explore the challenges in understanding consciousness - the differentials of the conscious states under different disease conditions.

They say, “Beauty lies in the eyes of the observer.” While physicists contradict one another in this, some, like Einstein, refused to believe in the subjectivity of physical reality till his last breath. Many founders of quantum mechanics believe in the non-local physical world, some hinting at the possibility of a parallel Universe. Physicists also talk about foundation problems, e.g., variations in Universal constants. The picture is entirely different regarding biology, where universal laws are almost non-existent. Challenges perceived by a neuroscientist may differ from those faced by a virologist or a cell biologist working on epigenetic changes. To put the matter briefly, we realised that the “grand challenges in biology” is a non-unique set whose definition depends on the knowledge domain of the specialists. But we agreed that there is one entity that poses similar challenges to physics, biology, psychology, neuroscience, and even Mathematics. That is consciousness. That key will open the secret of our existence in the true sense of the word. But there are numerous obstacles. One is the perception of this subject by a broad class of scientists. In fact, a comprehensive class of scientists denies accepting “consciousness” as a professional branch of science. They only consider this as a behavioral attribute. Some other people avoid talking about consciousness, assuming it is a meta-science that should never be permitted at the front door of science. I gradually discovered that some good scientists (primarily from physics) gave severe thoughts on consciousness research. I thought presenting a comprehensive appraisal of what the leading scientists think about this topic may have some future impact. So, I started on the journey. But like the heavenly river Mandakini, I went very slow, often forgetting where we started.

The book starts with some nostalgic moments from a seminar in which mathematical modeling of various aspects of life processes suddenly became bread and butter for various life scientists and physicists. The question of the Achilles heel remained: “What is consciousness?”. The starting chapter of the book debates some issues, such as whether the brain is the sole abode of consciousness. Questions like how to know the brain by slicing the brain is also raised. The book then describes the earlier efforts to model individuality consciousness and dissipative structures embedded in the life process. The book also attempts to bridge the connection between two abstract entities: consciousness and intuition. It then discusses the connection between consciousness and entropy. The concept of entropy is associated with the famous second law that states entropy of the universe will always increase. In information theoretic terms, it signifies that information loss is inevitable when it flows from the source to the destination. The book also highlights the difficulties in segregating the ‘source’ and ‘destination’ of information while associating the entropy or the information concept with the consciousness. The book then explores the cellular basis of consciousness and raises simple questions like whether cells also play games like conscious players. Can the incorporation of mitochondria in mammalian cells be considered an evolutionary game? This may also throw some light on the cellular basis of conscious behavior.

Lastly, the book tracks the cultural trace of consciousness, where we show how the concept of consciousness underwent a diffusion through our folktales and fables. The book also raises some legal and ethical issues related to consciousness.

It was Sridhar’s Bangalore home (Sridhar MK was my classmate at IIT Madras and a mentor of Suresh at IISc Bangalore) where the original plan of the book was initiated.

I dedicate this book to the memory of my mother, the late Smt. Bandana Dasgupta, who passed away in Oct 27. As a dynamic learner till her last breath, she guided me in finding references to consciousness in our ancient texts.

This book would only have been published with a push from Sridhar, the electrical engineer from IISc, whom I knew from my IIT days. When I almost lost hope about its possible publication, he kept my hopes alive. I must also acknowledge the meticulous proofreading by my son, Panini, a postdoctoral fellow at SNU in South Korea.

Contents

1

Some Nostalgic Chats

1.1 A Glimpse of 1978-79

IISc Bangalore was a kind of altar of initiation for me. The famous Prof. Satish Dhawan was the IISc director (1962-1981) at that time and was subsequently responsible for INSAT, a telecommunications satellite; IRS, the Indian Remote Sensing satellite; and the Polar Satellite Launch Vehicle (PSLV). Prof. G.N. Ramachandran, another famous scientist who narrowly missed (or was denied) the Nobel prize, was also a guest faculty member. These were the last few years of his career. At this stage, he formed a new school called the "Centre for Mathematical Biology", later renamed the "Centre for Theoretical Studies". I was fortunate enough to be in the audience at one of his lectures. It was a room in the central library premises. He was discussing the profound influences of complementary principles in physics and biology. His inspirations were derived from the DNA complementary strands. He mentioned that the basis of quantum mechanics is also the complementary nature of canonically conjugate pairs like position-momentum and energy-time. Then suddenly, he gave a shocker. For the first time, we understood what makes a scientist different from 'science-managers'. In his unorthodox style, he proposed the existence of a new kind of particle. Typically, we are used to particles that can be fixed in space but cannot be fixed in time. This new particle that he proposed would behave complementary to that. In other words, according to him, there should be a particle class that is fixed in time but cannot be contained in a bound space. It was rather difficult to conceive of particles that are bound in time but not containable in space. Was Prof. G.N. Ramachandran talking about consciousness or proto-consciousness much ahead of his time? The lecture haunts me till today. The last interaction I had with him is here:

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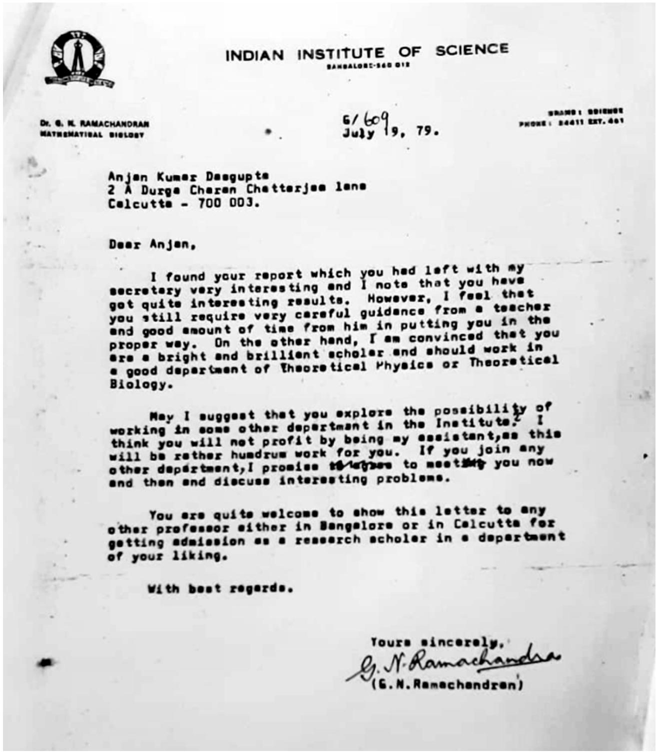

INDIAN INSTITUTE OF SCIENCE
BANGALORE-560 012

Dr. G. N. RAMACHANDRAN
MATHEMATICAL BIOLOGY

6/609
July 19, 79.

GRAMS: SCIENCE
PHONE: 34411 EXT. 461

Anjan Kumar Dasgupta
2 A Durga Charan Chatterjee lane
Calcutta - 700 003.

Dear Anjan,

I found your report which you had left with my secretary very interesting and I note that you have got quite interesting results. However, I feel that you still require very careful guidance from a teacher and good amount of time from him in putting you in the proper way. On the other hand, I am convinced that you are a bright and brilliant scholar and should work in a good department of Theoretical Physics or Theoretical Biology.

May I suggest that you explore the possibility of working in some other department in the Institute? I think you will not profit by being my assistant, as this will be rather humdrum work for you. If you join any other department, I promise to meet you now and then and discuss interesting problems.

You are quite welcome to show this letter to any other professor either in Bangalore or in Calcutta for getting admission as a research scholar in a department of your liking.

With best regards.

Yours sincerely,
G. N. Ramachandran
(G. N. Ramachandran)

1.2 The Entangled Birds

समाने वृक्षे पुरुषो निमग्नोऽनीशया शोचति मुह्यमानः |
जुष्टं यदा पश्यत्यन्यमीशमस्य महिमानमिति वीतशोकः ||

[मुण्डकोपनिषद् 3.1.2]

"samāne vṛkṣe puruṣo nimagno 'nīśayā śocati muhyamānaḥ
juṣṭaṁ yadā paśyaty anyam īśam asya mahimānam iti vīta-śokaḥ"
- Muṇḍaka Upaniṣad (3.1.2) and Śvetāśvatara Upaniṣad (4.7)

One Bird Eats the Fruit the other observes

"Two birds, inseparable companions, perch on the same tree; one eats the fruit, and the other observes. The first bird is our Self, feeding on the pleasures and pains of this world; The other is the universal Self, silently witnessing all."

1.3 The Dilemma of the Neuroscientists

Neuroscientists often suffer from the obsession that the brain bounds consciousness. So, consciousness research is implied to explore the brain and the cognition or behaviors of organisms with the brain. This belief network among neuroscientists inspired some researchers to steal Einstein's brain. On April 18, 1955, Thomas Stoltz Harvey was the pathologist at Princeton Hospital in New Jersey. His mission that night was to perform an autopsy on the body of the physicist Albert Einstein, who had just died. However, after the operation, Harvey decided to extract Einstein's brain and keep some parts of it to himself. According to Einstein's family, he wanted to be cremated to ensure that his body was not studied or stolen. However, Harvey decided to remove the physicist's brain, even without the proper authorisation of the hospital, to do what Einstein did not want: to study his brain and compare it with the brains of other people. This gigantic genius exploring the peculiarities of his brain slices would not reveal the uniqueness of his thought process. He was furious when Einstein's son, Hans, discovered something missing from his father's body. Incidentally, Harvey convinced him to grant permission to study the brain, hoping it would contribute to science history. While (Horwitz (2000)) made an excellent best-selling book, the subsequent book that recently appeared (Fenves (2019)) tells a different story. The section on Mythologies entitled "Einstein's Brain" mentions that splitting Einstein apart from himself falls under the category of the general theory of myths.

The close association of brain function and consciousness is what the neuroscientists believe. In support of this hypothesis, they pose evidence that damage to some brain regions can lead to a loss of consciousness. Additionally, research on patients with split-brain syndrome has shown that each hemisphere of the brain can support some aspects of consciousness but that a unified sense of consciousness requires communication between the two hemispheres. We should mention the views of Searle (2013) at this stage. Searle, one of the greatest scholars in this field, takes consciousness as the mind and asserts that we do not have many theories of consciousness. He also claimed that the many false claims made about its consciousness are like a scandal.[1]

Searle's criticism is centered around how the brain creates consciousness and models like the following:

- *Global workspace theory*: This theory suggests that consciousness is a product of the brain's ability to integrate information from different parts of the brain into a single, unified conscious experience.
- *Attention schema theory:* This theory suggests that consciousness is a product of the brain's ability to track its attention.
- *Integrated information theory:* This theory suggests that consciousness is a product of the brain's ability to integrate information in a coherent and meaningful way.

Other contesting theories do exist. The most recent approach is the possibility of having an artificial brain. The emergence of AI systems promotes this approach. AI tools can perform tasks that were once thought to be only in the exclusive domain of human brains. AI systems can learn, adapt, and develop new insights and knowledge. Some AI systems can experience emotions, even if these emotions are not experienced in the same way as humans.

The other question in this regard is the possibility of other living systems devoid of the brain to have consciousness. A strong candidate is plant-species Michael Pollan (2013). Plants can sense and respond to their environment. They can detect light, temperature, moisture, and chemicals and use this information to decide how to grow and develop. Plants can communicate with each other. They can do this through chemical signals and electrical impulses. Plants have a complex internal structure. They have cells, tissues, and organs, just like animals. Plants can also learn and adapt. They can remember past experiences and use this information to improve their chances of survival.

1.4 Limit of the Reductionist Approach

The traditional reductionist approach in biology is to understand something and dissect it into pieces - and the belief that one of those

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1 See <https://www.researchgate.net/publication/267334236>. The author, Kshitiz Upadhyay Dhungel, associated consciousness with the triad MANA-BUDHI-AHAMKARA. The author also supported criticism by Searle (2013) regarding the inadequacies of the consciousness theories.

pieces may carry the sought information. Ironically, biology provides the most significant evidence against the universal validity of this reductionist approach. A biologist is used to crush the cell and use the crude cellular extract to purify enzymes and characterise them. While this endeavor has utility in promoting our understanding and practically using the enzyme for some other purpose, the approach fails miserably in the case of mitochondria. One cannot study bioenergetics using crushed mitochondria. In the intact mitochondria, the gradient of protons across is needed to make it functional. Bioenergetics, in that sense, is non-existent with crushed subcellular components like mitochondria. No wonder mitochondria appear in the context of the futuristic biological discipline Usselman et al. (2016), which is called quantum biology. See Chapter 6 for a deeper discussion on this topic.

1.5 The Secret Life of Plants

The exclusive association of the brain with conscious behavior was first falsified by Sir J.C. Bose (Tandon (2019)). According to this author, his findings were so revolutionary at the time of their proclamation that this aroused disbelief and contradiction. Surprisingly, not many at that time took up such investigations and once accepted with reluctance, there was practically very little activity in the field for the next several decades. Hundred years later, recent advances in molecular biology, genomics, ecology, and neurophysiology have led to renewed interest in the mechanistic origin of consciousness, resulting in a flurry of activity, confirming most of Bose's observations". Conscious behavior, according to Bose, is not the monopoly of the brain, but it expresses itself in a different physiological route.

1.6 Some Hypotheses and Conjectures

Briefly, while reductionists have had remarkable success, the limitations of their approach are also apparent. Interestingly, as we go up from atoms to molecules, from molecules to cells, and from cells to organisms, the chance of discovering the essence of the holistic entity by cutting it into pieces falls drastically. Can we ever prove that the dog we love so much has such and such receptor in such and such cell and that the biochemical pathway of that "love" can be deciphered by cutting the dog into pieces and employing a patch-clamp on its brain slices? While common sense tells us that the answer is no, the belief that treating a genius like Einstein along with his great mathematical intuitions like a guinea pig would help to decode the complexity of his brain (say by slicing his brain) clubs to the set of unachievable goals, e.g., the perpetual machines of the first and second kind. We are familiar with several exclusion principles in physics, in which the inaccessibility of certain states is formalised. Pauli's exclusion principle states that two electrons in the same orbital must have opposite spins, which is one of the classy examples of such must-obey selection rules. Other examples related to the history of science are the impossibility of the existence of a perpetual machine of the first kind that will generate energy from nothing. This selection principle is the first law of thermodynamics. The equally important selection rule that follows is the impossibility of having a perpetual machine of the second kind. The second law states that no machine can convert one form of energy to another useful form (like work) with 100% efficiency. Interestingly, the third law of thermodynamics proposes another selection principle: the impossibility of attaining absolute zero. The third law is like saying, that you may be very near, but can never attain 0^{o}K. A similar selection rule also exists in the theory of special relativity, where we assure that a material particle can assume a velocity 99.99% of c (3.10^{8}msec^{-1}) but can never attain a velocity equal to the velocity of light (c). Thus, we can postulate that a real-life form cannot be dissected into an arbitrary number of pieces, and reassembling such pieces would reproduce the original life form. One may, however, argue that such practices are standard for surgeons on the organismic scale and molecular biologists on the cellular scale.

Note

However, the genius of Einstein cannot be understood by slicing his brain. Slicing and reassembling the slices should not be an ideal way to restore an organismic or cellular identity. However, such cleaving and ligating may be a perfectly acceptable procedure at the molecular level. Genetic cloning was revolutionized primarily by such practices.

We may cut the long story short by postulating that slicing and reassembling may be ineffective at the consciousness level. That may explain why we will never understand the complex thought process of Einstein by slicing his brain.

Observable(s) may assume complementary positions concerning consciousness (e.g., a Schrodinger cat can be live AND dead when in the confined box but can only be the live OR dead moment the box is open). In this case, the complementarity is between the two operators AND & OR. The Schrodinger cat in a box can have a quantum superposition of 'live' and 'dead' state, but the opened box will only have either live or dead. The cat in the box can be compared to an abstract AND operator, whereas the cat out of the box will be in an abstract OR state as it can be either alive OR dead.

2

Memories of Living State

In 1983, I was engaged as a Ph.D. Scholar at the Indian Institute of Chemical Biology (IICB). I attended a conference at the All-India Institute of Medical Science (AIIMS), New Delhi, organised by Dr. R.K. Mishra, a renowned scientist known for his non-conventional views on science, particularly Biophysics. Despite his unconventional approach, Dr. Mishra possessed remarkable organisational skills, allowing him to gather many well-known scientists from around the world.

Among the distinguished attendees, I vividly remember the late Prof. Ilya Prigogine, a Nobel laureate in Chemistry, and Prof. Harold Morowitz, renowned for his work on the energy flow in biology. Additionally, the mathematician Rene Thom, a proponent of catastrophe theory, and the Nobel laureate in Medicine George Wald (1967), famous for his research on the role of Vitamin A in the visual process, were also present. The conference saw participation from other disciplines, such as philosophy and religion. Witnessing such a diverse pool of experts coming together to discuss a complex theme in a seminar transcending disciplinary boundaries was fascinating.

During the conference, I had the opportunity to deliver a small oral presentation on the theory of ageing, focusing on the progression of reaction networks from cyclic to consecutive reactions.

2.1 Morwitz's Definition of Individuality

As a young scholar, I was familiar with the work of Prof. Morowitz (Morowitz (1987)) as he had the privilege of being one of his post-doctoral fellows. Through his Ph.D. supervisor, Dr. J. Das, I became acquainted with Prof. Morowitz, who had been mentored by Prof. Jack Maniloff, who had worked closely with Morowitz. Everyone admired Morowitz for his groundbreaking contributions to the field of thermodynamics in biology. In one of his notable papers (Maniloff and Morowitz (1972)), he predicted that Mycoplasma is the thermodynamically feasible size of the smallest bacterium. The prediction is still valid. Mycoplasmas are the smallest free-living organisms, with a diameter of about 0.2-0.3 micrometers. They are so small that they do not have a cell wall and rely on their cell membrane to maintain their shape.[1]

However, it was surprising to see Prof. Morowitz participating in a session almost related to metaphysics during the life-defining seminar. In his book "Mayonnaise and the Origin of Life: Thoughts of Minds and Molecules" (1985), Morowitz discussed how the combination of oil, vinegar, and egg yolk in mayonnaise served as a model for compounds that exhibit opposing properties, such as fat and water. These compounds form cell boundaries and connect molecules, resembling life's self-replicating units. While the book was published in 1985, his session in the "Living State" seminar occurred a few years prior. He may have conceptualised this "coacervate" origin of life during that time.

Morowitz's talk was based on a simple hypothesis: the concept of the "self" is only possible through compartmentalisation. According to him, our own selves, and the world around us are significant components of this coacervate theory.[2] Russian biochemist Aleksander Oparin and British biologist J.B.S. Haldane independently proposed this theory in the 1920s. Morowitz extended this concept to the definition of the life process or self. He argued that without such compartmentalisation, our responses to the environment or our ability to send signals would hold no meaning.

As a person focused on thermodynamics, Morowitz may have been motivated by the concept of a "system." If a system is closed, it is destined to become disordered, and to sustain an ordered state akin to life, it must be open. However, the minimal requirement for the

1 Other bacteria are smaller than Mycoplasma but not free-living. For example, some bacteria that live inside cells, such as rickettsia and chlamydia, can be as small as 0.1 micrometres. However, these bacteria are not considered free-living because they cannot survive outside a host cell.

2 It is worth mentioning that the coacervate theory is significantly similar to the segmentation problem in image processing. The critical issue here is to separate objects from the background and individuals from the environment.

existence of such a system is the presence of a boundary that topologically distinguishes the system from its surroundings.

Note

Morowitz's postulate states that the definition of life or self can only be achieved if we consider that biochemical processes occur within a topologically closed vesicular space. In this context, we must note that for chemiosmotic coupling to occur, we need intact (rather than crushed) cellular boundaries. The protonmotive force can remain only across a topologically closed compartment.

Coacervates as precursors of self

2.2 Is Seeing Believing? Conjectures from Prof. George Wald

I distinctly recall the thought-provoking opening remarks of Prof. George Wald during his presentation. With a dramatic tone, he asked, "We see, but does the frog see?" As a pioneer in vision systems, he delved into the validity of the visual perception process from a consciousness perspective. Prof. Wald contended that frogs do not truly "see" in the way humans do. Instead, their retinas respond to light stimuli, similar to the way biomolecules are excited by various interactions. However, the crucial question remained: Can we definitively prove that a frog perceives and comprehends its surroundings, whether it be the presence of another frog, a snake, or a human?

Retina excited by photons, or seeing?

Seeing is commonly associated with believing, as we often rely on visual perception to validate our understanding. However, Prof. George Wald's statement challenges this notion by suggesting that the belief system of a frog might be fundamentally different. This concept brings to mind the bacterial sensing-based conjectures put forth by Berg (H. C. Berg (1975), H. Berg (1988)). In discussing how a physicist views bacterial chemotaxis, Berg argued that sensing in chemotaxis is a well-defined chemical process. Bacteria can utilise this process to perform a computational task, specifically discerning the vectorial direction of an attractant and subsequently adjusting their molecular mechanism to move in that direction – a process, in itself, driven by vectors.

However, the question remains: Does this prove that bacteria are conscious of the presence of the attractant? During the early days of biophysics, chemotaxis was regarded as a potential molecular foundation for neuroscience. The belief was that by studying chemotaxis, one could construct a simplified model of consciousness, providing insights into the underlying mechanisms.

Note

George Wald proposed that vision holds a distinct connotation separate from mere seeing. While a conscious individual can see and subsequently describe, perceive, and appreciate beauty or ugliness, a robot, on the other hand, may possess a form of vision, but it remains unlikely that there will ever be definitive proof that it has indeed "seen" something. The essence of Wald's argument lies in the notion that vision encompasses a deeper level of conscious experience beyond the simple act of visual perception

2.3 Life Process as a Dissipative Structure: Prigogine

When Illya Prigogine took the stage, he appeared to embody the spirit of a particular European scientific tradition that seamlessly integrated physics and philosophy. His intellectual foundation drew inspiration from the ideas of the renowned French philosopher Henry Bergson (Bergson (1998)), who advocated concepts such as "élan vital" and the notion that intuition precedes essence. Prigogine's remarkable contributions to the field of non-equilibrium thermodynamics earned him a Nobel Prize in Chemistry.

During his presentation, Prigogine expounded on the utilisation of excess entropy, symbolised by $\delta^2 S$, as a Lyapunov function, as exemplified by the work of Qian (2002). This approach allowed for a deeper understanding of the dynamics of complex systems and their evolution over time. Prigogine's insights shed light on the intricate interplay between thermodynamics and the emergence of order and complexity in systems far from equilibrium.

$$\delta^2 S \leq 0$$

$$\delta/\delta t(\delta^2 S) \geq 0.$$

The Lyapunov function $\delta^2 S$, originating from the Hamiltonian principle, is a mathematical concept introduced by the renowned Russian mathematician Lyapunov (Smirnov (1992)). Building upon this foundation, Prigogine further expanded the understanding of thermodynamics by introducing the notion of the thermodynamic limit, beyond which dissipative structures emerge (Nicolis (1977)). In living systems, there is always a departure from equilibrium. Prigogine proposed that these dissipative structures hold the key to understanding the processes of life. This departure from equilibrium becomes possible when we surpass the thermodynamic limit, within which stability laws would inevitably drive the system towards equilibrium. Equilibrium, in the context of living bodies, occurs only after death when the body becomes inert.

According to Prigogine, the existence of the "élan vital," a concept akin to consciousness in his description, is supported by dissipative structures that exist far from equilibrium. In this view, life becomes an ongoing struggle against the inexorable approach towards the equilibrium state. Prigogine presented his famous "Brusselator model," named after his own Brussel school, to illustrate the concept of dissipative structures in a simple chemical system. In ordinary chemical reactions, the system tends towards equilibrium. However, in oscillatory reactions (e.g., the Belusov-Zhabotinsky reaction), there is an onset of oscillatory behavior, which Prigogine interpreted as the emergence of dissipative structures resulting from self-organisation processes.

Prigogine's ideas captivated the entire audience. However, he struggled to provide a definitive answer when asked about the metric that could accurately express the true distance from equilibrium. Additionally, some attendees raised concerns about the ideal solution approximation frequently employed in his derivations. It was discovered that deviations from ideal solution behavior could lead to the onset of unstable behavior in systems that are close to equilibrium (Dutta, Dasgupta, and Das (1987)).

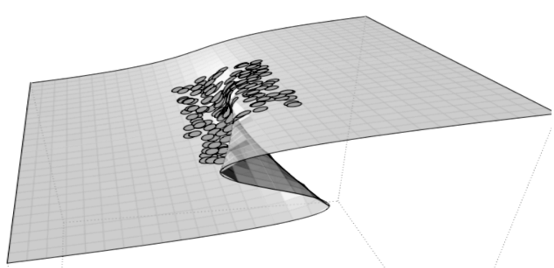
Note

According to Prigogine, the emergence of dissipative structures within the living process is intimately tied to its deviation from equilibrium. These dissipative structures manifest when the system reaches a thermodynamic limit, where novel behaviors and patterns arise. In contrast, the absence of life or death drives a system inexorably towards equilibrium, where all processes come to a standstill. Prigogine's perspective Emphasises the dynamic nature of life, with dissipative structures serving as the defining characteristic distinguishing living systems from inert ones.

2.4 Catastrophe Theory - Rene Thom

The term "catastrophe," derived from the French language in this context, refers to the abrupt nature of transitions and does not inherently carry negative connotations. One prominent advocate of catastrophe theory was the colorful French mathematician René Thom (Thom (1977)). Interestingly, Thom missed the first day of his participation in the conference due to his enjoyment of the hospitality at the hotel in New Delhi. This eccentric behavior reminded us of the unconventional brilliance often associated with French artists.

During Thom's lecture, we attentively listened as he described catastrophe theory as a mathematical framework for understanding the sudden changes in the psychological states of conscious beings. His unique perspective shed light on the potential mathematical underpinnings of these abrupt transformations, providing a fascinating glimpse into the intricate dynamics of the human psyche.



Cusp Catastrophe

In its original form, the critique of the theory stemmed from the fact that it was devoid of any stochastic inputs (Poston and Stewart 1996).

> **Note**
>
> The central thesis of catastrophe theory is rooted in the idea that seemingly abrupt transitions or singularities in a system's parameter space can be understood by interpreting them as folds and cusps on manifolds. This perspective enables the application of smooth, differentiable models to explain and analyze phenomena that exhibit apparent discontinuities. By embracing this approach, the theory offers a framework to reconcile and comprehend the relationship between smooth mathematical models and the often-discontinuous nature of observed phenomena.

In simpler terms, catastrophe theory explains that when certain controlled factors or parameters of a system reach a critical point, it can trigger a sudden and discontinuous change in the system's behavior. This abrupt transformation is referred to as a catastrophe. During Thom's lecture, he attempted to apply this theory to describe specific psychological abnormalities, viewing it as a subject of analogy.

While there were limitations to the future development of Thom's theory, particularly in ecology and biology, the fundamental concept of catastrophes remains intriguing when considering conscious perception in living beings. In the flow of our daily lives, we often experience moments that unexpectedly alter the course of our thoughts and emotions regarding the external world. These instances align with the essence of Thom's mathematical concept, highlighting the potential relevance of catastrophe theory in understanding such shifts in conscious perception.

2.5 Theory of Ageing (Anjan Kr Dasgupta)

Among the various lectures presented at the seminar, the one I delivered holds a special place in my heart. Despite being presented four decades ago, the work remains unpublished. However, I still cherish this shared simple model of ageing.

Death and ageing are intrinsically linked to the state of being alive. When it comes to modelling ageing, two main schools of thought emerge program theory (Horvath and Raj (2018)) and error catastrophe theory (Orgel (2001)). Program theory suggests that ageing is predetermined, like the process of morphogenesis. According to this perspective, ageing follows a predetermined program encoded within an organism. On the other hand, error catastrophe theory proposes that ageing arises from chance events that gradually accumulate errors within the system.

These two theories offer contrasting explanations for the ageing process, with program theory emphasising predetermined factors and error catastrophe theory highlighting the role of chance events. Both perspectives contribute to our understanding of ageing, shedding light on different aspects of this complex phenomenon.

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graph G {
 layout=neato


 Ageing -- Error;
 Error -- Repair;
 Error --ConsecutiveReactions;
 ConsecutiveReactions --Catastrophe;
 Ageing -- Program;
 Repair -- Program;
 CyclicReactions -- Program;

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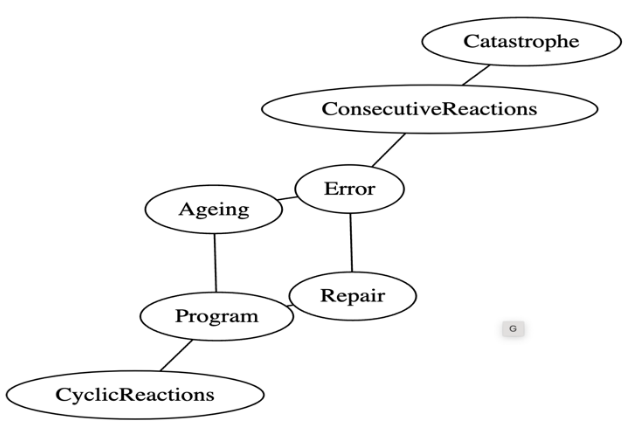


Network of Aging

In most metabolic cycles and repair processes associated with the timeline of life, two distinct classes of reaction pathways can be identified: consecutive reactions and cyclic reactions. The accumulation of certain processes, such as error-causing metabolites like free radicals, typically falls into the category of consecutive reactions. On the other hand, metabolic cycles are comprised of cyclic reactions. An example of this can be seen in the proton pumping process within mitochondria. As long as the synchronised cycle of proton outflow resulting from electron transport and its subsequent flow through the F1-F0 ATPase complex remains intact, there will be no accumulation of reactive oxygen species. However, any disruption in synchrony between these two processes can lead to the opposite scenario.

To some extent, error correction mechanisms, like the action of superoxide dismutase, can prevent the accumulation of errors. However, when these mechanisms fail, there is a significant disruption in coupling. In a two-state system, this breakdown corresponds to the failure of oxidative phosphorylation. Consequently, when the consecutive component predominates, catastrophic events like death can occur. In other words, the ageing model we propose represents a progression towards death under specific circumstances.

The proposed ageing theory can be summarised as follows: The charts provided illustrate the two main classes of reaction networks. Please note that the reversibility of individual reaction pathways is not shown, and the illustrations serve as skeletal representations of the network types. In the case of consecutive reactions, the adjacency matrix D can be represented as D = D_{ij}, where only $D_{i,i+1} \neq 0$. In contrast, cyclic reactions exhibit feedback loops or self-loops, implying the existence of some k and l such that $D_{i-k}, D_{k,l}, D_{l,i} \geq 0$. Conversely, no such k-l pairs should exist in consecutive reactions. Furthermore, in cyclic reactions, the number of reaction pathways (r) is always less than the number of components (n), i.e., $n > r$. For instance, in a simple cyclic triangular reaction A -> B -> C -> A, both n and r are equal to 3. Conversely, in a parallel consecutive reaction A -> B -> C, we have n = 3 and r = 2.

2.5.1 Consecutive Reactions

```
graph G {
 layout=neato
 A -- B;
 B -- C;
 C -- D;
 D -- E;

}
```

2.5.2 Cyclic Reactions

```
graph G {
 layout=neato
 A -- B;
 B -- C;
 C -- D;
 D -- E;
 E --A;

}
```

If we represent a biochemical reaction network using two base states, |Cycl> and |Cons>, the overall state of aging, |Ag>, can be expressed as:

$$|Ag> = Pcycl * |Cycl> + Pcons * |Cons>$$

Here, Pcycl and Pcons represent the probabilities of cyclic and consecutive reactions, respectively. To express Pcycl, we can write:

$$Pcycl = <Cycl|Ag>$$

Similarly, Pcons can be defined as:

$$Pcons = <Cons|Ag>$$

According to the ageing model, if Pcons > Pcycl, the system will age in a direction that leads to the gradual disappearance of all cycles.

Caution

The ageing theory described above is proposed without any simulations, and the arguments are based on a qualitative assessment of the gerontological process. However, it can serve as food for thought for future simulations and further exploration.

3

Consciousness as an Evolutionary Entity

Should the term "consciousness" be used in scientific discourse? Both scientists and experts from other liberal arts brands are divided on this. While looking into possible course curriculums initiated by different universities, we found one University, <nu.edu>, that offers a course on "Master of Arts in Consciousness and Transformative Studies".

Consciousness According to social media, AI platforms like ChatGPT are the state of being aware of one's thoughts, feelings, and surroundings. This awareness connection is probably derived from Crick's astonishing hypothesis (Crick and Clark (1994)). The central assumption in Crick's theory is that consciousness is subjective, human, and a typical attribute of the human brain. It emerges from the interactions of neurons in the brain. If we abide by the evolutionary theory that unifies structures and functions of various life forms, consciousness is expected to have an evolutionary history.

3.1 Sentience

Sentience is the ability to experience feelings and sensations. It is the capacity to be aware of oneself and one's surroundings. Sentience is considered a necessary condition for consciousness but is not the same. Consciousness is the ability to be aware of oneself and one's experiences.

Some evidence suggests that plants may be sentient to some degree. For example, plants have been shown to respond to stimuli in ways that suggest they are aware of their surroundings. For example, plants will turn their leaves towards the sun to maximize sunlight exposure. Additionally, plants have been shown to release chemical signals when they are injured or stressed. These signals can alert other plants to the danger and attract predators to the injured plant.

3.2 Cosmic Consciousness

Erwin Schrödinger, a pioneering quantum physicist, delved deep into the interplay between Eastern philosophy and Western science, proposing a radical idea: the existence of a singular, universal consciousness. The Schrodinger's equation derived from the eastern philosophy was:

$$Atman = Brahma = Consciousness$$

The corollary of this universal consciousness concept led to drawing parallels between the intricate networks of neurons in the human brain and the vast interconnected galaxies. The other corollaries that followed were Panpsychism and Integrated Information Theory. Panpsychism sees consciousness everywhere, whereas Integrated information theory, with its ϕ value, offers a method to test this, potentially linking philosophy and science. If we explore the Gaia Hypothesis that portrays Earth as a self-regulating organism, it is again in accordance with Schrodinger's timeless equation. The anthropic principle also matches with such principles.

3.3 Cambridge Declaration of Consciousness (CDC)

A declaration that can be termed as a Darwinian interpolation of consciousness is the Cambridge Declaration on Consciousness (2012). The Declaration was publicly proclaimed in Cambridge, UK, on July 7, 2012, at the Francis Crick Memorial Conference on Consciousness.

Note

According to the Cambridge Declaration, non-human animals, including all mammals and birds, and many other creatures, including octopuses, possess neurological substrates that are complex enough to support consciousness.

3.4 CDC versus Descartes

The French philosopher René Descartes (1596 - 1650) maintained that animals cannot reason and do not feel pain; animals are living organic creatures, but they are automata, like mechanical robots.

Descartes held that only humans are conscious, have minds and souls, and can learn and have language; therefore, only humans deserve compassion (Thomas (2020)).

3.5 Limitations of CDC

The major limitation of the CDC approach is that it links consciousness with the evolution of the brain or neurological circuit. If we adhere to the Darwinian content of the CDC, can't we hypothesise that the evolution of consciousness was rooted in more primitive forms of life, e.g. microorganisms? This approach has one limitation, namely the scaling of consciousness. The meaningful manifestation of consciousness may only be reflected in eukaryotes, which can exhibit multicellular behavior. In the next section, we will probe into a toy model of consciousness when we assume that a fusion of a bacteria-like cell occurs with Archaea so that an independent organismic entity is formed. This is the case with mitochondria assimilated in a host cell to form primitive eukaryotes. We describe this fusion as a minimal model of consciousness in which intelligent, cooperative behavior can emerge due to this assimilation. Mitochondria are believed to have originated from a symbiotic relationship between primitive eukaryotic cells and alpha-proteobacteria.

Note

This symbiotic relationship is thought to have occurred around 1.5 billion years ago. According to the endosymbiotic theory, the ancestral eukaryotic cell engulfed the alpha-proteobacterium, and over time, the bacterium evolved into a permanent resident of the cell, eventually becoming the mitochondrion.

The bacterium benefited the eukaryotic cell by producing energy in the form of ATP through cellular respiration. In return, the eukaryotic cell provided the bacterium with a protected environment and access to nutrients. Over time, the relationship between the bacterium and the eukaryotic cell became mutually beneficial and interdependent, leading to the evolution of the mitochondrion as a permanent organelle within the eukaryotic cell. The mitochondrion and the eukaryotic cell evolved together, eventually becoming so integrated that they function as a single entity. Mitochondria are a fundamental part of eukaryotic cells and essential for energy production. The endosymbiotic relationship between the ancestral eukaryotic cell and the alpha-proteobacterium provides a remarkable example of how symbiotic relationships can drive evolution and shape the biology of organisms.[1]

3.6 Game Theory Approach

Let us ask a simple question that relates Games to consciousness. Can there be a game between two players where each is unconscious?[2]

3.6.1 Nash Equilibrium

Both cannot communicate, they are separated in two individual rooms. The normal game is shown below:

	Prisoner B stays silent (*cooperates*)	**Prisoner B betrays (*defects*)**
Prisoner A stays silent (*cooperates*)	Each serves 1 year	Prisoner A 10 years Prisoner B: goes free
Prisoner A betrays (*defects*)	Prisoner A: goes free Prisoner B 10 years	Each serves 5 years

It is assumed that both understand the nature of the game, and that despite being members of the same gang, they have no loyalty to each other and will have no opportunity for retribution or reward outside the game.

---

1 The Hard Problem of Consciousness: This theory states that consciousness is an emergent brain property but is not reducible to physical processes. In other words, consciousness is more than the sum of its parts. The Dualism Theory: This theory states that consciousness is a separate substance from the physical body. This substance is often referred to as the soul. The Reincarnation Theory: This theory states that consciousness is reborn into a new body after death. The Near-Death Experience Theory: This theory states that consciousness can survive the death of the brain and that near-death experiences are evidence of this. None of the theories addresses whether a machine can mimic conscious behaviour.

2 A game requires two or more players who are conscious and aware of the game's rules. If all players are unconscious and cannot understand the game's rules or decide how to play, the game ceases to exist. There are some games that one player can play, but these games do not require the player to be unconscious. For example, a puzzle game can be played by one player who is trying to solve a series of puzzles. However, even in these games, the player is still conscious and aware of what they are doing. Some games, such as brain-training games, are designed to be played by unconscious players. These games are designed to stimulate the brain and improve cognitive function. However, these games are not actual games in the traditional sense. They are more like exercises or training programs. So, while there are some games that one player can play, no games can be played between unconscious players. A game requires conscious players who can understand the rules and make decisions.

In 1950, an American mathematician, John Nash, came up with his decision-making model, famously known as the Nash equilibrium.

> **Note**
>
> In the game shown in the table above, Nash equilibrium is a condition in which each player only has a specific set of strategies to choose from (the 2,2 element of the table). Since every player is rational and wants the best possible outcome, no one would dare to change their strategy unilaterally.

For example, if all the countries possess similar strengths and weaknesses, none would wage a war against each other, as it would not be in their best interest. If a country decides to do so, others might form a coalition against it. One corollary of it is that nuclear deterrents during the Cold War. Since both the superpowers had similar strategic options, they never waged war against each other.

3.6.1.1 Prisoner's Dilemma

	Stay silent	**Betray**
Stay silent	-1,-1	-3,0
Betray	0,-3	**-2,-2**

- There is 1 NE (Nash Equilibrium)
- Both players betray (Highlighed in bold).
- This is a dominant strategies NE.
- It is also the only non-Pareto optimal outcome in this game.

3.7 Evolutionary Biology

Game theory was first applied to evolutionary biology by John Maynard Smith, a British evolutionary biologist and geneticist. Maynard Smith was one of the first scientists to use mathematical models to study the evolution of behaviour and species interactions.

In the 1970s and 1980s, Maynard Smith developed a series of mathematical models that incorporated game theory to study the evolution of cooperation and altruism. He introduced the concept of an "evolutionarily stable strategy" (ESS), which refers to a strategy that cannot be overcome by any other strategy when the game is played repeatedly over time. Maynard Smith used game theory and the concept of ESS to explain the evolution of cooperation and the maintenance of altruism in populations of animals.

Maynard Smith's contributions to evolutionary biology have been highly influential, and his work continues to be widely cited in the scientific literature. He is widely regarded as one of the pioneers of the application of game theory to evolutionary biology, and his contributions have paved the way for further research on the evolution of cooperation and altruism in animals and humans.

3.8 Falsifiability of Consciousness

Falsifiability is a concept in the philosophy of science that refers to the ability of a theory to be tested and potentially shown to be false through empirical observations or experiments. According to the idea of falsifiability, a theory that cannot be tested or potentially disproven is not scientifically valid.

In the context of consciousness, falsifiability arises because consciousness is a subjective experience that cannot be directly observed or measured. This makes it challenging to develop testable hypotheses about consciousness and devise experiments to verify or falsify them.

One approach to addressing the problem of falsifiability in consciousness research is to focus on the neural and physiological processes that are thought to underlie consciousness and to develop testable hypotheses about these processes. For example, researchers might study subjects' brain activity while experiencing different states of consciousness, such as waking, sleeping, or being under anesthesia, and compare these activity patterns to see if they can identify any specific neural markers of consciousness.

Another approach is to study the behaviour of conscious organisms and see if any characteristics can be used to distinguish them from unconscious or non-conscious systems. For example, researchers might study the ability of conscious animals to learn, make decisions, or adapt to their environment and compare these abilities to those of unconscious or non-conscious systems.

Ultimately, the question of falsifiability in consciousness research is a complex and ongoing topic of debate, and a complete understanding of consciousness will likely require the development of new theories and approaches that can be tested and potentially falsified.

3.9 Plant Consciousness

There is ongoing debate and speculation about whether plants might have some form of consciousness or awareness. Some people believe that plants can sense and respond to their environment in ways that suggest a level of consciousness or awareness. In contrast, others argue that plants do not have the complex nervous systems or cognitive abilities necessary for consciousness.

There is evidence that plants can respond to stimuli in their environment, such as light, temperature, and the presence of other plants or animals. For example, plants can adjust their growth and development in response to changes in light levels, and some species can even alter their chemical composition in response to the presence of herbivores. Some researchers have suggested that these responses may be evidence of a rudimentary form of consciousness or awareness in plants.

However, it is essential to note that the nature of consciousness and how it arises is still not fully understood, and a complete understanding will likely require the development of new theories and approaches. We need to understand the underlying mechanisms of consciousness better before we can determine definitively whether plants or other non-animal organisms are capable of experiencing consciousness in the same way humans and other animals do.

3.10 Astonishing Hypothesis

In the language of Crick (Crick and Clark (1994)), "You do not win battles by debating exactly what is meant by the word battle. Consciousness is a subject about which there is little consensus, even as to what the problem is".

Crick starts with a scale of consciousness. He states, "It is probable, however, that consciousness correlates to some extent with the degree of complexity of any nervous system. When we clearly understand, in detail and principle, what consciousness involves in humans, then it will be time to consider the problem of consciousness in much lower animals."

3.11 Can Consciousness Exist Without a Brain?

Kelly and Marshall (2021) in the book entitled "Consciousness Unbound: Liberating Mind from the Tyranny of Materialism" raises a unique point. Can the mind exist without the brain?

According to Kena Upanishad (Ch. 1 Verse 6), "Think NOT of the mind, but of THAT by which the mind is thought". Consciousness (Chetanaa) is the driving force of the Mind (Chitta). Without Consciousness, the mind is equivalent to "Jada".

The reducing valve theory is thus consistent with this multilayered approach to define or describe consciousness. The Upanishadic term "Chitta" is closer to consciousness, which drives the mind, which may behave as an inert entity.

Note

The notion that the brain acts as a reducing valve for consciousness was supported by Henri Bergson Barnard (2012) and Aldous Huxley (1954),Poller (2019), and could offer us an alternative to the brain-only view of consciousness

The current brain-related description is consistent with the broader description of consciousness. The brain may be a specialised filtering unit of consciousness. However, any subcellular organelle can act as a driving force of consciousness. Let us recapitulate the analogy:

- A conditioning unit flows cool, clean air but does not produce the air; it merely extracts air from outside, cooling it and filtering out impurities.
- A washbasin tap does not generate water but regulates the flow.
- Blinds do not create light. They permit the transmission of light into the room.
- Being born and being in the mother's womb are only different stages of consciousness, irrespective of what the current trends of "pro-life" movements or their opponents might be.

In the last few decades, the reductionist brain-only description of consciousness ruled the roost. Presently, a large section of the scientific community is open to the Bergsonian and Huxley schools of thought. The conflicting description comes when one raises a debate that strictly at such a date, the baby in the mother's womb becomes conscious and that timing is decided by a gross physical or physiological completeness of the to-be-born baby. We call it conscious only when the womb-residing entity is sufficiently similar to a human. While we talk about Panpsychism, cosmopsychism, neutral and dual-aspect monisms, and idealist monism, Velmans, Kelly, and Marshall (2021) in the real-life definition of consciousness and writing to abort a baby are dealt with a certain degree of arbitrariness. The artificial boundary between consciousness and non-conscious behaviour may be the root cause of such conflicts. The monopoly of humans to be conscious also comes from this artificial boundary. The all-encompassing Upanishadic theory, and to some extent, the valve theory proposed by the Huxley-Bergson school of thought, are fortunately free from such dogma. The enabling of such a theory would also behave as a catalyst to end the mindless pro-life, pro-abortion debates. Rights of whom? Of the conscious or the non-conscious? The right-owners have only a diffused boundary between them.

A worldview in tune with the "filter theory" is based on biocentrism (Lanza and Berman (2010)). The author, Robert Lanza, is widely acknowledged as one of the fathers of applied stem cell biology. The biologist Robert Lanza proposed a bold new theory of the universe that builds on the insights of quantum physics to put consciousness at its centre. So, the inner presumption in Lanza's theory matches well with the Upanishadic thoughts that Consciousness is pivotal in creating all the matter in the Universe. His theory is based on the "consciousness" of "observers", based on which we talk about the reality in the quantum world. Without a conscious observer, the quantum measurement is impossible. On the other hand, the observers bring lives to Schrodinger cats. Without the observer, the Schrodinger cat's existence is in a perpetually hybrid state of life and death.

3.12 Orch OR Orchestrated Objective Reduction

The three keywords for the Orch OR theory introduced by Hameroff and Penrose (1996, 2014) are

- Microtubules [3]
- Quantum jitters [4]

---

3 Microtubules are the tiny, hollow building blocks inside your cells that act like a cellular skeleton. Made from protein subunits called tubulin, they form long, thin tubes 25 nanometers wide. They are the key players in maintaining cell shape, transporting organelles, and enabling cell division (mitosis). Unlike static scaffolding, microtubules constantly grow and shrink, allowing cellular changes. They are present in all eukaryotic cells, which include animals, plants, and fungi.

- Objective reduction [5]

Some key publications in this field are by Penrose (1989), Penrose (1994), Hameroff and Penrose (1996). Some critics of the Orch OR theory are McKemmish et al. (2009) and Baars and Edelman (2012). The main argument of the critics of Orch OR theory is that the brain is too warm, wet, and noisy an environment for quantum coherence to be maintained. Quantum coherence, essential for the Orch OR theory, is extremely sensitive to environmental disturbances (decoherence). The argument is that decoherence would occur too quickly for quantum processes to have any functional role in the brain. The counterargument of this criticism is best provided by Sahu et al. (2013), who showed that a single brain-neuron-extracted microtubule is a memory-switching element whose hysteresis loss is nearly zero, implying the emergence of a super-cooled condition.

3.13 Bell's Theorem and Beyond

> **Warning**
>
> An event in one part of the world cannot instantly affect what happens far away. This is the locality in physics. Violation of locality results in "spooky action at a distance".

Albert Einstein, in 1935, raised questions on the completeness of quantum mechanics as it permits "spooky action at a distance". In 1964, Northern Irish physicist John Stewart Bell demoted locality from a cherished principle to a testable hypothesis.

---

4 Quantum jerks are random fluctuations in the energy field at the quantum level, as predicted by the uncertainty principle. The term was used by Hameroff and Penrose (2014) to correlate quantum coherence decoherence with consciousness.

5 Objective reduction (OR) is a theoretical process in quantum mechanics that proposes a physical explanation for the wave function collapse. Roger Penrose, a physicist, suggests this objective collapse might be linked to consciousness. He has not specified the exact mechanism but proposes a connection to spacetime geometry. It is possible that he indirectly used the Ventantic analogy of two birds, one enjoying the fruits and the other observing. The observation is the process that collapses, which will happen when the two birds remain close to each other.

Tip

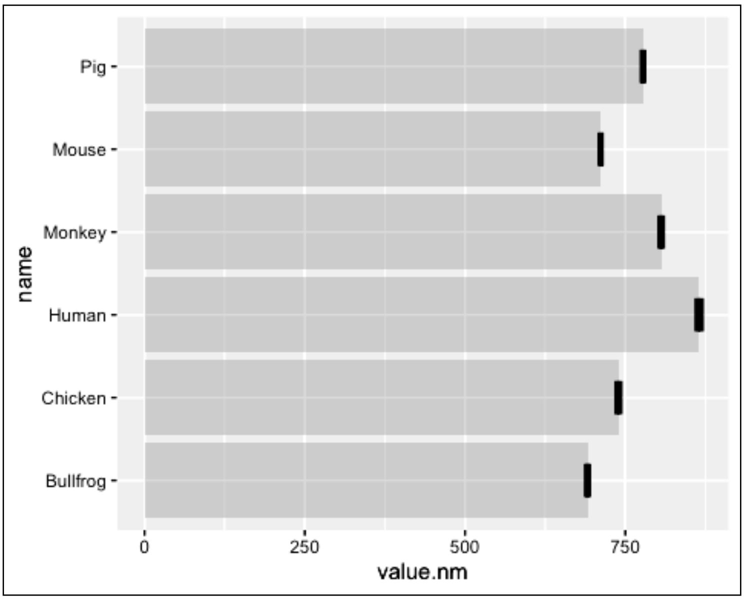
Bell proved that quantum mechanics predicted stronger statistical correlations in the outcomes of specific far-apart measurements than any local theory possibly could.

3.14 The Photonics of Consciousness

We mentioned the limitations of "sliced brain" analysis. However, conventional science has a strong bias toward a reductionist approach. Sometimes, such a reductionist approach does provide some clues toward holism. Brain bio-slices are activated in response to Glutamate. They emit photons in different wavelength bands. Interestingly, the band wavelength strongly depends on the phylogenetic status of the species. Biophotons are photons associated with the brain. A spectral red shift was observed in animals like bullfrogs, mice, chickens, pigs, and monkeys, as well as in humans. The slices from human beings, which are supposed to be the most intelligent among these species, were most red-shifted (Z. Wang et al. (2016)).

```
require(ggplot2)

Loading required package: ggplot2

species<-c('Bullfrog', 'Mouse', 'Chicken', 'Pig',
'Monkey', 'Human')
lambdamax<-c(691.2,711.8,739.2,777.7,806.1, 865.3 )
lamsd<-c(0.98,0.0,1.96,0.75,1.49,2.74)

dataphot<-data.frame(
name=species,
value.nm=lambdamax,
sd<-lamsd)

ggplot(dataphot) +
 geom_bar( aes(x=name, y=value.nm), stat="identity",
fill="gray", alpha=0.5) +
 geom_errorbar( aes(x=name, ymin=value.nm-sd,
ymax=value.nm+sd), width=0.4, colour="black",
alpha=0.9, size=1.3) +
 coord_flip()
```

```
Warning: Using `size` aesthetic for lines was
deprecated in ggplot2 3.4.0.
ℹ Please use `linewidth` instead.
```



3.15 The Chemical Origin of Consciousness

Sometimes, scientists are humorous while describing serious subjects. Einstein's story (maybe fake) goes like this. While explaining time dilation to a young girl without any formal background in science, he said that when you talk to your fiancee, one hour seems like one second, and when you touch a hot iron rod, then 1 second seems like one hour.

> **Note**
>
> "The only thing we are sure about consciousness is that it is soluble in chloroform"- Luca Turin https://physicsworld.com/a/do-quantum-effects-play-a-role-in-consciousness

Anesthetics are used to depress the peripheral and central nervous systems (CNS) by blocking nerve conduction to facilitate surgical and other noxious procedures (Schmeltz and Metzger (2007)).

Anesthetics can be divided into general (inhalation and parenteral) and local types, the former inducing a loss of waking consciousness in humans similar in many respects to sleep, while the latter blocks local nerve conduction. Parenteral anesthetics are also termed intravenous hypnotics or intravenous induction agents and can be used alone or in combination with other agents. Although evidence has suggested that microRNAs (miRNAs) significantly impact cognitive function and are associated with the etiology of several neuropsychiatric disorders, their expression in sevoflurane‑induced neurotoxicity in the developing brain has not been characterised. In the present study, the miRNA expression pattern in neonatal hippocampus samples (24 h after sevoflurane exposure) was investigated, and nine miRNAs were selected, associated with brain development and cognition, to perform a bioinformatic analysis. Previous microfluidic chip assays detected 29 upregulated and 24 down regulated miRNAs in the neonatal rat hippocampus, of which 7 selected deregulated miRNAs were identified by the quantitative polymerase chain reaction. A total of 85 targets of selected deregulated miRNAs were analysed using bioinformatics. The main enriched metabolic pathways, mitogen‑activated protein kinase, and Wnt pathways may have been involved in molecular mechanisms of the neuronal cell body, dendrite, and synapse. The observations of the present study provided a novel understanding regarding the regulatory mechanism of miRNAs underlying sevoflurane‑induced neurotoxicity, therefore benefitting the improvement of the prevention and treatment strategies of volatile anesthetics-related neurotoxicity.

3.16 EPR

There is a small section in the Yaksha-Yudhisthira Conversation in Mahabharata. The Yaksha asks Yudhisthira what is faster than the wind. Yudistira responds without any hesitation that the mind is faster than the wind. In a 1935 paper (Einstein, Podolsky, and Rosen (1935)), Einstein, Boris Podolsky, and Nathan Rosen introduced a thought experiment to argue that quantum mechanics was not a complete physical theory. Known today as the "EPR paradox," the thought experiment was meant to demonstrate the innate conceptual difficulties of quantum theory. It said that a measurement result on one particle of an entangled quantum system can have an instantaneous effect on another particle, regardless of the distance between the two parts. The information between entangled particles can thus travel at a speed faster than light. This case is, apparently, beyond the selection rule posed by the theory of relativity that no material particle can have velocity faster than light. The information between entangled systems crosses this relativistic barrier.

Copenhagen's interpretation is often taken to subscribe to a solution to the measurement problem offered in terms of John von Neumann's projection postulate. In 1932 [1996], von Neumann suggested that the entangled state of the object and the instrument collapses to a determinate state whenever a measurement takes place. Quantum mechanics could not describe this measurement process, a type 1 process, as he called it; it can only describe type-2 processes, i.e., the development of a quantum system in terms of Schrödinger's equation. In his discussion of the measurement problem, von Neumann then distinguished between (i) the system observed, (ii) the measuring instrument, and (iii) the actual observer. He argues that during a measurement, the actual observer gets a subjective perception of what is going on with a non-physical nature, distinguishing it from the observed object and the measuring instrument. However, he holds on to psycho-physical parallelism as a scientific principle, which he interprets as such that a physical correlation exists to any extra-physical process of the subjective experience. So, in every case of a subjective perception, we must divide the world into the observed system and the observer. However, where the division takes place is partly arbitrary. According to von Neumann, it is contextual whether the dividing line is drawn between the description of the observed object (i) and the measuring instrument together with the observer (ii) + (iii) or it is drawn between the description of the observed object together with the measuring instrument, i.e., (i) + (ii), and the observer (iii). In other words, von Neumann argues that the observer can never be included in a type 2 process description, but the measuring instrument may sometimes be part of a type 2 process. However, it gives the same result concerning the observed object (i). An essential consequence of von Neumann's solution to the measurement problem is that a type 1 process occurs only in the presence of the observer's consciousness. Furthermore, even when von Neumann considers the situation in which the descriptions of (i) and (ii) are combined, he talks about the interaction between the physical system (i) + (ii) and an abstract ego (iii) (Neumann 1932 [1996], Ch VI). Therefore, the mind seems to play an active role in forming a type 1 process, which would be incompatible with psycho-physical parallelism.

3.17 The No-cloning Theorem

The no-cloning theorem is a result of quantum mechanics which forbids the creation of identical copies of an arbitrary unknown quantum state (Wootters and Zurek (1982)). It was stated by Wootters, Zurek, and Dieks in 1982 and has profound implications in quantum computing and related fields. The theorem follows from the fact that all quantum operations must be unitary linear transformations on the state (and potentially an ancilla).

The celebrated quantum no-cloning theorem establishes the impossibility of making a perfect copy of an unknown quantum state. The discovery of this critical theorem for the field of quantum information is currently dated 1982. However, Park (1970), Park provided an explicit mathematical proof of the impossibility of cloning quantum states.

3.18 Leibniz's Principle of Identity of Indiscernibles

The Principle of the Identity of Indiscernibles, Ladyman and Bigaj (2010), Kalafut (2020), according to which, in one version, there cannot be distinct things that are qualitatively precisely alike, can seem supremely important. On the truth or falsity of this principle (hereafter: PII) turn the issues of the nature of objects and their individuation, the nature of space, time, and matter, the possibility of innate ideas, and even the metaphysical basis of love: if, as the PII seems to imply, things are nothing over and above their qualitative character, the truth or falsity of the PII promises to shed light on the question of whether we love individuals in virtue of their qualities or whether love is instead directed fundamentally at the individuals themselves. All of these are metaphysical issues and love, too! Who can deny that the PII is worthy of our philosophical attention?

However, there is a slight problem for proponents of the PII. What could be easier than to conceive of two perfectly similar things? Moreover, what could be more irresistible than to point out the foibles of the misguided advocates of the PII? Thus, we have a cottage industry in which, fittingly enough, similar counterexamples to the PII are, as it were, mass-produced. No wonder the number of proponents of the PII is vanishingly tiny. Although this is not the occasion to develop this point, we think these counterexamples can be effectively challenged.

3.19 Notes on Leibniz's Principle and the Notion of Uniqueness

The impossibility of cloning an unknown quantum state is one of the basic rules governing quantum physics Yao et al. (2014). This statement, known as the "no-cloning theorem", prohibits perfect cloning but does not oppose approximate copying. This paper will prove that no perfect cloning can be achieved due to uncontrollable quantum fluctuations. Such a situation allows us to treat the no-cloning theorem as equivalent to Leibniz's principle and further unify them under the notion of uniqueness; that is, any physical entities (whether macroscopic or microscopic objects) in nature would have their individuality. Moreover, we demonstrate the universality of the unique scheme by showing that any process of constructing one exactly symmetrical or asymmetrical body of a physical object is forbidden. On the whole, nature does not allow the existence of entirely identical, symmetrical, or asymmetrical things, and this conclusion is valid for all physical domains. Briefly, in quantum mechanics, the no-cloning theorem implies that due to the laws of quantum mechanics – particularly the linearity of quantum evolution – it is impossible to duplicate an unknown quantum state perfectly. This is significant because quantum states are not deterministic in the same way classical states are; they are described by wave functions that encompass a range of probabilities. Attempting to clone an unknown quantum state would require measuring it, which would collapse the wave function and alter the state itself due to quantum measurement's inherent disturbance. The impossibility of perfect cloning as dictated by quantum physics thus suggests a profound natural law that reinforces the individuality of all physical entities. This law reflects a deeper order in the universe where each particle or object maintains a distinct identity governed by quantum mechanics and broader physical principles. By connecting this to philosophical notions like Leibniz's principle, we underscore the universal nature of uniqueness in microscopic and macroscopic realms.

3.20 The Parallels between Upanishads and the Leibniz's Principle

The Upanishads often explore the idea of the uniqueness and indivisibility of the Self or Atman. The Atman is considered eternal, unchanging, and unique to each being. Just as quantum physics forbids the duplication of an exact quantum state, the Upanishads emphasise that the essence of an individual soul cannot be replicated or divided. It is singular and distinct. The Upanishads often explore the idea of the uniqueness and indivisibility of the Self or Atman. The Atman is considered eternal, unchanging, and unique to each being. Just as quantum physics forbids the duplication of an exact quantum state, the Upanishads emphasise that the essence of an individual soul cannot be replicated or divided – it is singular and distinct.

3.21 Questions from the Chapter

- Can we extrapolate it to the non-existence of self-replicating robots?
- Can we also extrapolate that perfect copying of the genetic state is impossible?
- Can we say that no twins are identical?

4

Intuition Versus Consciousness

Let us start with a question: Can a machine have intuition? We need to have a formal definition of intuition for this purpose. [1,2,3,4]. Some examples of machine intuition research may be illustrative here. [5]. While many of these hypothetical questions are unlikely to have unique answers, we may ask a more straightforward question: Can intuition be compared to dreams? The American dream is obviously different from the Indian dream. The intuitions are likely to be

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1 Some people define intuition as a non-rational form of knowledge acquired through experience or a gut feeling. Others define it as a form of reasoning based on subconscious knowledge or associations. Still, others define it as a form of perception that is not based on the senses.

2 If we define intuition as a non-rational form of knowledge, then it is not easy to see how a machine could have intuition. Machines are typically programmed to follow rules and procedures, and they do not have the ability to make decisions based on gut feelings or subconscious knowledge.

3 However, if we define intuition as a form of reasoning that is based on subconscious knowledge or associations, then it is possible that a machine could have intuition. Machines can be programmed to learn from their experiences, and they can store this knowledge in their memory. This knowledge can then be used to make decisions that are not explicitly programmed into the machine.

4 For example, a machine trained to play chess may be able to make intuitive decisions about how to move the pieces. This is because the machine has learned from its experiences and has stored this knowledge in its memory. The machine can then use this knowledge to make decisions that are not explicitly programmed into it.

5 Several research projects are exploring the possibility of machines having intuition. One such project is the DARPA SyNAPSE program, which develops a brain-inspired machine that can learn and make decisions like a human. Another project is the IBM Watson project, which is developing a machine that can answer questions in a human-like way.

different. The intuition of a historian may differ drastically from that of a trained scientist, even if they speak the same language.

4.1 The Dictionary Meaning and the Linguistic Essence of Intuition

- Ability to understand or know something immediately based on feelings rather than facts. (Cambridge)
- Intuitions are unexplained feelings that something is true even without evidence or proof. (Collins)
- The ability to understand something instinctively, without conscious reasoning. (Oxford)

We may justify this diagram by asking a coupled question - Can a dog be intuitive? Dogs can often sense when their owners are feeling sick or upset. Dogs can sometimes find people who are lost or injured. However, we cannot know the explicit nature of a dog's intuition as we need to understand its language. Now, let us scale up this question of intuition among people who do not understand each other's language. For example, a Chinese, a Russian and an American are sitting in a room and asked to intuit about some danger that will happen and then narrate it. Even if they speak out, they will only understand what they are guessing if a fourth person who understands all these languages brings them to the scene. The problem with this solution is that the description of this interpreter may be entirely different from that of another interpreter, as there is a level of uncertainty in the comprehension of each interpreter. Rudimentary things like the fear of assassination may be understood, but not beyond that. A reverse experiment may also be interesting. Suppose we have a group of interpreters who understand all the languages. Now, they are given the task of guessing each other's mother tongue. Can they ever do it? [6].

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6 Gopal Bhar is a fictional character in a Bengali folktale series. In one of the Gopal Bhar tales, titled "The Test of Native Language," Gopal Bhar was presented with a unique challenge. A foreigner was accused of stealing and brought before the king's court. The foreigner claimed not to understand the local language, which raised suspicions about his guilt or innocence. The king and his courtiers were puzzled, as they could not communicate with the accused to ascertain the truth. Gopal Bhar, known for his wit, stepped in to find a solution. He asked the king for permission to handle the situation. Gopal Bhar then devised a clever plan to determine the accused man's native

4.2 Probability of Being Conscious

There are several different estimates of the improbability of our existence, but they all point to the fact that it is incredibly unlikely. One estimate by astrophysicist Brandon Carter (Carter (1974)) puts the odds of our existence at 1 in 10^{120}. This number in the denominator is so large that it is difficult to comprehend. It is estimated that there are 10^{80} atoms ($1.661 \cdot 10^{56}$)in the observable Universe, so the odds of our existence are equivalent to randomly picking one atom out of the entire Universe and finding that it is a copy of your entire body.

Note

Another estimate, by physicist Frank Tipler (Tipler (1994)), puts the odds of our existence at 1 in $10^{10^{120}}$. The denominator is an even larger number than Carter's estimate. Tipler's estimate is based on the fact that the laws of physics are so finely tuned that they allow for the existence of life. If the laws of physics were even slightly different, life as we know it would not be possible.

The Universe is incredibly vast, and it is estimated that there are billions of galaxies, each containing billions of stars. However, only a tiny fraction of these stars will likely have planets that could support life. The conditions for life to exist are very specific. For example, the Earth's atmosphere must contain the right mix of gases, and the Earth's temperature must be within a specific range. The evolution of life is also a very improbable process. Life took billions of years to evolve from simple single-celled organisms to complex multicellular organisms like humans. Given all of these factors, it is clear that our existence is incredibly improbable. However, we are here, and we should cherish our existence. We are a part of something much larger than ourselves, and we have the potential to make a difference in the world.

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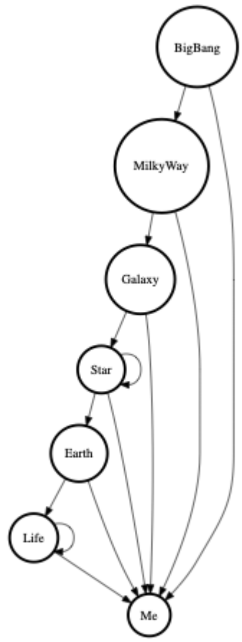
language. He placed food items from different regions before the accused, each originating from a distinct country with its language. Gopal Bhar observed the accused's reactions as he saw the food items. When the man showed recognition and enthusiasm for a specific food item, Gopal Bhar deduced that it was likely the food from his native land. This indicated that the accused understood the language associated with that food.

To what extent intuition played a role in our journey towards this highly improbable evolutionary journey is anyone's guess.



4.3 Evolution of Intuition: Cognitive Science Versus Evolutionary Biology

One prominent theory is that intuition is a product of our evolutionary history and has adaptive value. According to this view, our ancestors faced numerous challenges and uncertainties in their environments, and the ability to make quick, accurate, and contextually appropriate decisions would have conferred a survival advantage. Intuition may have evolved due to natural selection, favouring individuals who could rapidly process sensory information, recognise patterns, and make effective decisions without extensive cognitive analysis.

Note

Another perspective is that intuition is rooted in the cognitive processes that underlie perception and learning. Through repeated exposure to certain stimuli or situations, the brain can develop implicit knowledge and associations that guide intuitive responses. This acquired knowledge, often called "intuitive expertise," allows individuals to recognize familiar patterns and make rapid judgments based on prior experiences.

Cognitive scientists have also proposed that intuition relies on heuristics, mental shortcuts or rules of thumb that help simplify decision-making processes. These heuristics result from cognitive biases that have developed over time as a way to process information and make judgments efficiently. While heuristics can be beneficial in many situations, they can also lead to errors and biases.

It is important to note that intuition is not a singular, well-defined concept but rather a broad term that encompasses various cognitive processes. A combination of genetic factors, environmental pressures, and cultural influences likely influences the evolution of intuition. It emerged through gradual refinement and optimisation, allowing humans to navigate their environments and make adaptive decisions efficiently.

Further research is needed in this direction to gain a more comprehensive understanding of the evolutionary origins of intuition. Scientists continue to explore the cognitive mechanisms, neural processes, and genetic underpinnings that contribute to intuitive thinking to shed more light on its evolutionary history. Here are some of the factors that can affect the probability of intuition leading to a correct decision: - Experience: People with more experience in a particular area are likelier to have developed strong intuitions about that area. For example, a doctor who has seen many patients with a particular condition is more likely to have a good intuition about how to treat that condition. - Knowledge: People with more knowledge about a particular topic are also more likely to have developed strong intuitions about that topic. For example, a financial analyst who has studied the stock market for many years is more likely to have a good intuition about which stocks are likely to go up in value. - The situation at hand: The situation can also affect the probability of intuition leading to a correct decision. For example, if a person is faced with a situation very similar to one they have faced before, they are more likely to rely on their intuition to make a decision. However, if a person faces a situation very different from anything they have faced before, they may be less likely to rely on their intuition. They may instead choose to make a decision based on more rational factors.

4.4 Philosophical Debates

- In Indian philosophy, intuition is often regarded as a significant aspect of human cognition and spiritual development. Various philosophical traditions in India, such as Vedanta, Yoga, and Buddhism, offer insights into the nature and significance of intuition. Intuition is seen as a direct, unmediated awareness of truth, meaning intuition is not based on reason or evidence but simply a direct, unmediated awareness of something. Intuition is seen as a higher form of knowledge than reason. This is because reason is limited by the senses and by the mind. Intuition, on the other hand, is not limited by the senses or by the mind. It is a direct, unmediated awareness of truth. Intuition is seen as a necessary condition for moksha. It is the state of liberation from the cycle of birth and death. Intuition is seen as a necessary condition for moksha because it allows us to experience the truth of Brahman directly.

- Descartes: Descartes believed intuition is a direct, unmediated awareness of truth. He argued that intuition is infallible and the only reliable source of knowledge. For example, Descartes believed that he could intuit the truth of his existence. He argued that when he doubted his own existence, he was still aware of himself as a doubting being. This awareness, he argued, was an intuition of his existence.
- Kant: On the other hand, Kant believed that intuition is a product of the mind's interaction with the world. He argued that intuition is not infallible and is not the only source of knowledge. Kant argued that intuition is a necessary but insufficient condition for knowledge. In other words, intuition provides us with the raw materials for knowledge, but more is needed to guarantee that our knowledge is true. We also need to use reason to combine and interpret the data provided by intuition.

4.5 Descartes and Kant and their proximity to the Indian School

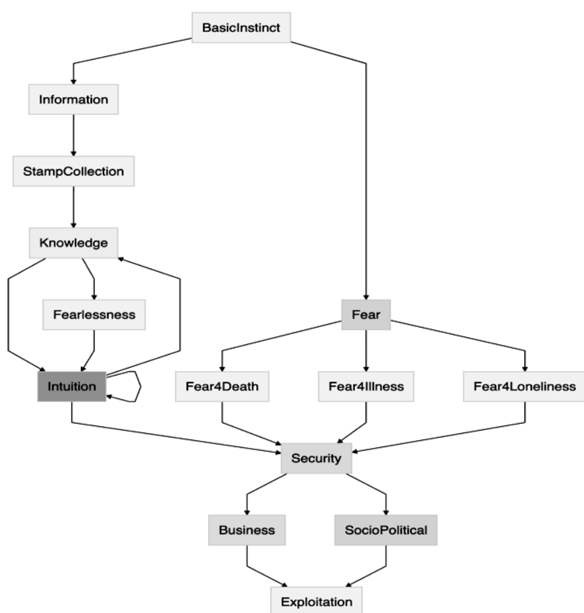
Characteristic	Descartes	Kant
Nature of intuition	Direct, unmediated awareness of truth	'roduct of the mind's ıteraction with the world
Reliability of intuition	Infallible	Not infallible
Relationship to reason	Intuition is the only reliable source of knowledge	Intuition is a necessary condition for knowledge, but not sufficient

Relationship to Indian philosophy	Closer	Further

A Critique of Intuition

- The advise from the supervisor of Wilder: "Do not let your intuition fool you"
- It is the conception that an unclouded and attentive mind provides.
- Contrarian view: According to Kant, the concepts of time and space derived from an a priori intuition are independent of experience.

4.6 A Flow Diagram for Psychological aspects of intuition



4.7 The Champion of Intuitive Progress - Henry Bergson (1859 – 1941)

Henri Bergson was a prominent French philosopher who significantly impacted both analytic and continental philosophy, particularly during the first half of the 20th century. His philosophical ideas challenged traditional notions of rationalism and scientific reductionism, emphasising the importance of immediate experience and intuition in understanding reality.

4.8 élan vital

One of Bergson's most famous concepts is "élan vital," which translates to "vital impulse" or "life force." According to Bergson, the Universe is not merely a collection of static objects governed by mechanical laws but a dynamic and evolving reality driven by this vital impulse. Bergson believed that this élan vital is the creative force behind the evolution of life forms and the development of consciousness.

4.9 Who Were Influenced by Bergson's Work?

- Albert Einstein: Einstein greatly admired Bergson's work and credited Bergson for helping him develop his theory of relativity.
- William James: James was a pioneer in Psychology and was influenced by Bergson's work on the nature of consciousness.
- Charles Sherrington: Sherrington was a Nobel Prize-winning neuroscientist, influenced by Bergson's work on the brain and nervous system.
- Illya Prigogine (Chemistry Nobel), who introduced the concept of symmetry-breaking instabilities and dissipative structures in chemistry, was also a big fan of Bergson.
- Russell and others argued for a more rational and analytical approach to philosophy based on logical reasoning and empirical evidence. Despite his influence and recognition, Bergson thus faced criticism from Bertrand Russell, who disagreed with his emphasis on intuition and his metaphysical approach.

4.10 Table: Highlights of the Bergson Russel disagreement

Aspect of Conflict	Henri Bergson	Bertrand Russell
Approach to Philosophy	Emphasised intuition and immediate experience as crucial for understanding reality	Advocated for a logical and analytical approach to philosophy based on logical reasoning and empirical evidence
Metaphysics	Proposed the concept of "élan vital" as a	Criticized metaphysical concepts and argued for a

	vital impulse driving evolution and consciousness	reductionist and scientific worldview
Perception of Time	Viewed time as a subjective experience of continuous flow and duration	Argued for a scientific and objective understanding of time, influenced by Einstein's theory of relativity
Knowledge and Truth	Valued intuitive knowledge and saw it as complementary to intellectual knowledge	Focused on logical analysis and Emphasised the pursuit of intellectual truth
Influence on Science	Believed that science should incorporate intuition and experience in addition to rationalism	Argued for a purely rational and empirical approach to science, dismissing metaphysical elements

4.11 Bergson and Russel Debate in AI development

- The Bergson school has influenced the development of AI systems capable of learning and adapting in a way that is more akin to human learning than traditional rule-based AI systems. For example, the AI system known as "DeepMind" was inspired by the Bergson school's emphasis on intuition and creativity.
- The Russell School has influenced the development of AI systems that are capable of solving complex problems using logical reasoning. For example, the AI system known as "Watson" was inspired by the Russell School's emphasis on logic and reason.
- Recent work on hybrid AI has sought to combine the insights of the Bergson school and the Russell school in order to develop AI systems that are both creative and logical. For example, the AI system known as "Sophia" is a hybrid AI system capable of learning and reasoning.

4.12 Penrose-Hawkins Debate

4.12.1 On Human Brain vs. Computers

The Penrose-Hawkins debate was a series of discussions between the British physicist Roger Penrose and the American computer scientist Stephen Hawking about the nature of consciousness and the possibility of artificial intelligence. Penrose argued that consciousness is a non-algorithmic phenomenon that the laws of physics cannot explain as we currently understand them. Hawking argued that consciousness is a product of the brain and that it is possible to create conscious artificial intelligence.

The Penrose-Hawkins debate is still ongoing, and a clear consensus on the issue needs to be established. However, the debate has helped raise awareness of artificial intelligence's philosophical and scientific challenges.

4.13 Intuition Versus Rationality Debate

The intuition vs rationality debates are a series of discussions about the relative importance of intuition and rationality in human thought. Some people believe that intuition is the more important of the two, while others believe in rationality.

- Several arguments have been made in favor of intuition. One argument is that intuition is often faster and more efficient than rationality. Another argument is that intuition is often more accurate than rationality, especially when there is insufficient information to make a rational decision.
- Several arguments have also been made in favor of rationality. The argument is that rationality is more reliable than intuition. Rationality is more objective and independent of emotions and biases.

Points to note: Although there are striking similarities between the two debates, the respective terminology differs - In the Hawkins-Penrose debate, rational thinking has been replaced by algorithmic thinking.

4.14 Intuitive Futurism - Ray Kurzweil's Singularity

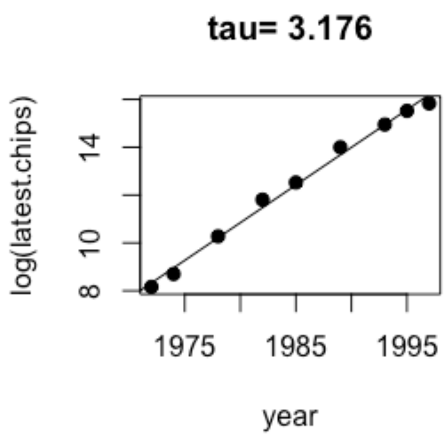
- Ray Kurzweil, a director of engineering at Google, is a well-known futurist with a track record for accurate predictions.
- Kurzweil said, "The year 2029 is the consistent date I have predicted when artificial intelligence will pass a valid Turing test – achieving human levels of intelligence.

4.15 Moore's Law Revisited

Assume that

$$n = no \cdot exp(t/\tau)$$

```
latest.chips<-
c(3500,6000,29000,134000,275000,1200000,3100000,55000
00,7500000)
year<-c(1972,1974,1978,1982,1985,1989,1993,1995,1997)
lmdl<-lm(log(latest.chips)~year)
ll<-sprintf("tau= %.3f",(1/lmdl$coefficients[2]))
plot(year,log(latest.chips),pch=19,main=c(ll))
abline(lmdl)
```



4.16 Interpretation

One can pack twice as many transistors on an integrated circuit every two years, doubling the number of components on a chip and its speed.

4.17 Consider These Diverse Exponential Trends

- The exponentially slowing pace that the Universe followed, with three epochs in the first billionth of a second, with later salient events taking billions of years.
- The exponentially slowing pace in the development of an organism. In the first month after conception, we grow a body, a head, and a tail. We grow a brain in the first couple of months. After leaving our maternal confines, our physical and mental maturation is rapid at first. In the first year, we learn primary forms of mobility and communication. We

experience milestones every month or so. Later on, key events march ever more slowly, taking years and then decades.

4.18 The Exponential Trend Continues

- The exponentially quickening pace of the evolution of life forms on Earth.
- The exponentially quickening pace of the evolution of human-created technology, which picked up the pace from the evolution of life forms.
- The exponential growth of computing. Note that the exponential growth of a process over time is just another way of expressing an exponentially quickening pace. For example, achieving the first MIP (Million Instructions per Second) took about ninety years for a thousand dollars. Now, we add MIP per thousand dollars every day. The overall innovation rate is clearly accelerating as well.

4.19 Moore's Law on Integrated Circuits, the Fifth Paradigm Versus Other Exponential Trends

- Many questions come to mind:
- What is the common thread between these varied exponential trends?
- Why do some of these processes speed up while others slow down?
- And what does this tell us about the continuation of the exponential growth of computing when Moore's Law dies?
- Is Moore's Law just a set of industry expectations and goals, as Randy Isaac, head of basic science at IBM, contends?
- Or is it part of a more profound phenomenon that goes far beyond the photolithography of integrated circuits?
- After considering the relationship between these apparently diverse trends for several years, the surprising common theme became apparent.
- What determines *whether time speeds up or slows down?* The consistent answer is that time moves in relation to the amount of chaos. We can state the Law of Time and Chaos as follows:

4.20 Law of Time and Chaos

- The Law of Time and Chaos: In a process, the time interval between salient events (that is, events that change the nature of the process or significantly affect the future of the process) expands or contracts along with the amount of chaos.
- When *there is much chaos in a process, significant events take more time to occur*. Conversely, *as the order increases, the periods between salient events decrease*.
- We have to be careful here in our definition of chaos. It refers to the quantity of disordered (that is, random) events that are relevant to the process.

4.21 The Law of Increasing Chaos (LIC)

- As chaos increases exponentially, *time exponentially slows down* (the interval between salient events grows longer as time passes).
- This fits the Universe rather well. When the entire Universe was just a "naked" singularity, a perfectly orderly single point in space and time – there was no chaos, and conspicuous events took almost no time.
- As the Universe grew in size, chaos increased exponentially, and so did the timescale for epochal changes.

4.22 LIC Contd.

- Now, with billions of galaxies sprawled out over trillions of light-years of space, the Universe contains vast reaches of chaos and, indeed, requires billions of years to get everything organised for a paradigm shift to take place.
- We see a similar phenomenon in the progression of an organism's life. We start as a single fertilized cell, so there is only limited chaos there, ending up with trillions of cells, and chaos dramatically expands.
- Finally, our designs deteriorate at the end of our lives, engendering even greater randomness. So, the period between salient biological events grows longer as we age. Moreover, that is indeed what we experience.

- But the opposite spiral of the Law of Time and Chaos is the most important and relevant for our purposes. Consider the inverse sub-law, the *Law of Accelerating Returns*.

4.23 The Law of Accelerating Returns (LAR)

- As order exponentially increases, time exponentially speeds up. That is, the time interval between salient events grows shorter as time passes.
- The Law of Accelerating Returns (to distinguish it from a better-known law in which returns diminish) applies specifically to evolutionary processes.
- In an evolutionary process, order – the opposite of chaos – is increasing. Moreover, as we have seen, time speeds up.

4.24 Law of diminishing returns (LDR)

The law of diminishing returns states that in all productive processes, adding more of one factor of production while holding all others constant ("ceteris paribus") will, at some point, yield lower incremental per-unit returns. The law of diminishing returns does not imply that adding more of a factor will decrease the total production, a condition known as negative returns, though this is common.

4.25 Intuition in Science

Intuition has played a role in many scientific discoveries. For example, Isaac Newton had an intuitive feeling that the force of gravity must be inversely proportional to the square of the distance between two objects. This intuition led him to develop his gravitation theory, one of the cornerstones of modern physics.

Albert Einstein also had a strong intuition about the nature of the Universe. He once said, "The only real valuable thing in science is intuition." Einstein's intuition led him to develop his theory of relativity, which revolutionised our understanding of space, time, and gravity.

4.26 Intuition in Technology

Intuition has also played a role in many technological innovations. For example, Steve Jobs had an intuitive feeling that people would want to use personal computers that were easy to use and visually appealing. This intuition led him to develop the Macintosh computer, one of the first personal computers to be successful with the general public.

Bill Gates also had a strong intuition about the potential of the Internet. He once said, "The internet is the most important invention since the printing press." Gates's intuition led him to found Microsoft, which became one of the most successful technology companies in the world.

4.27 Being Counterintuitive

The counterintuitive nature of certain phenomena or ideas often leads to fruitful insights and discoveries. When something is counterintuitive, it means it goes against our intuitive expectations or common sense. This can challenge our existing beliefs and mental models, forcing us to reconsider and explore alternative explanations or possibilities.

4.28 Bell's Theorem and the Peak of the Counterintuitiveness

Bell's inequality is a mathematical constraint that limits the possible results of experiments involving entangled particles. It was first proposed by John Stewart Bell in 1964.

The inequality states that if one has two entangled particles and one measures them both, the results of the measurements cannot violate certain mathematical relationships. If they do, then it means that the particles must be communicating with each other faster than the speed of light or that there are some hidden variables unknown to us.

- *Local realism* is a theory that says that everything that happens in the Universe can be explained by local interactions between particles, meaning that if there are two far apart particles, they cannot instantly influence each other's behavior.
- *Hidden variables* are hypothetical variables not included in quantum mechanics but could potentially explain some of its strange features. For example, hidden variables could explain why entangled particles seem correlated, even when a large distance separates them. Bell's theorem shows that if local realism is true, certain mathematical relationships cannot be violated. However, experiments have shown that these relationships are indeed violated, meaning either local realism is false or hidden variables must exist.

Note

The Copenhagen interpretation rejects the idea of local realism and the idea of hidden variables. This is because the Copenhagen interpretation holds that quantum mechanics is a complete theory and that there is no need to add any hidden variables to explain its behaviour. The Copenhagen interpretation also takes a non-local view of the Universe, which means that it does not believe that the Universe is made up of separate parts that interact locally. Instead, the Copenhagen interpretation believes that the Universe is a unified whole and that everything that happens in the Universe is interconnected.

Let us now refer back to that talk by GNR in which he postulated an entity that can be fixed in time but cannot be confined to a space (see section 1.1). The idea falls in line with Copenhagen's interpretation.

4.29 Bell's Theorem in the Context of Consciousness

Bell's mathematical theorem shows that certain aspects of quantum mechanics cannot be explained by classical physics. This has led some people to argue that Bell's theorem has implications for consciousness. One of the critical aspects of quantum mechanics that Bell's theorem relates to is entanglement. Entanglement is a phenomenon in which two particles are linked together in such a way that they share the same fate, even if a large distance separates them, which means that if someone measures the state of one particle, he instantly knows the state of the other particle, no matter how far away it is.

Bell's theorem shows that entanglement cannot be explained by classical physics. This is because classical physics assumes that particles have well-defined properties, such as position and momentum, even when they are not being measured. However, entanglement shows that particles do not have well-defined properties until they are measured.

Some people have argued that Bell's theorem has implications for consciousness. They argue that if entanglement is genuine, it means there is some non-local connection between particles. This connection could be a form of consciousness, or it could be something else.

However, it is essential to note that Bell's theorem does not prove that consciousness exists. It simply shows that classical physics cannot explain entanglement. Other possible explanations exist for entanglement, such as the idea that particles are not separate entities but part of a larger whole.

4.30 Information and Intuition

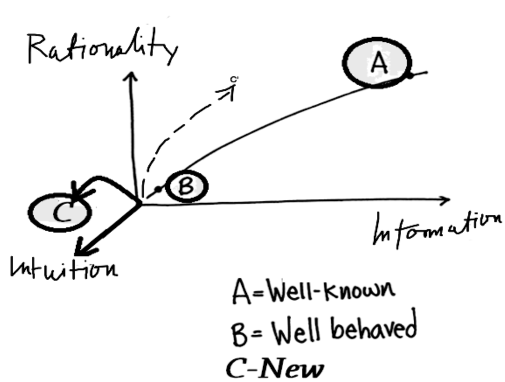
The brief analysis we have outlined can be summarised as follows: The entropy, which is akin to Shannon entropy, may have real and imaginary parts. - The real part corresponds to information on how to interpret the imaginary part, which is also called the phase Shannon entropy. - We may interpret this *phase Shannon entropy* as intuition. - A surprising outcome of the said description is that while for a given thermodynamic system, the information is unique, we can have multiple intuitive guesses about the same system (technically speaking, the existence of a multiplicity of phase Shannon entropy is an eventuality) Nalewajski (2016).

4.31 Inference

The root question raised in this presentation is whether intuition is a metaphysical entity that only occurs to specific individuals, such as lightning, and is intrinsically non-computable.

The complex entropy interpretation of intuition indicates a complementary nature of information and intuition, and the introduction of its hidden metaphysical existence becomes unnecessary.

The multivalued nature of the Shannon phase entropy might enable us to create a new paradigm of quantum superposition-like principle.



Whether a machine can have intuition is a complex question that philosophers and scientists have debated for many years. There is no easy answer, as the definition of intuition is itself contested.

Some people define intuition as a non-rational form of knowledge acquired through experience or a gut feeling. Others define it as a form of reasoning based on subconscious knowledge or associations. Still, others define it as a form of perception that is not based on the senses.

If we define intuition as a non-rational form of knowledge, then it is not easy to see how a machine could have intuition. Machines are typically programmed to follow rules and procedures, and they do not have the ability to make decisions based on gut feelings or subconscious knowledge.

However, if we define intuition as a form of reasoning that is based on subconscious knowledge or associations, then a machine could have intuition. Machines can be programmed to learn from their experiences and store this knowledge in their memory. This knowledge can then be used to make decisions which are not explicitly programmed into the machine.

For example, a machine trained to play chess can make intuitive decisions about moving the pieces. This is because the machine has learned from its experiences and has stored this knowledge in its memory. The machine can then use this knowledge to make decisions that are not explicitly programmed into it.

So, while it is difficult to say definitively whether a machine can have intuition, it is possible that machines could develop the ability to make intuitive decisions in the future. This would require machines to learn from their experiences and store this knowledge in their memory.

Several research projects are exploring the possibility of machines having intuition. One such project is the DARPA SYNAPSE program, which is developing a brain-inspired machine that can learn and make decisions like a human. Another project is the IBM Watson project, which is developing a machine that can answer questions in a human-like way.

These projects are still in their early stages, but they have the potential to develop machines with a level of intuition comparable to humans. This could have a significant impact on the way we interact with machines, and it could also lead to new ways of understanding the human mind.

5

Consciousness and Entropy

The first thing that comes to one's mind when one hears about entropy is that this is a metric of disorder. Spontaneous processes show an increase in entropy. Thus, entropy is also associated with the arrow of time. The pessimistic belief that a system will always go to a state of disorder as time passes has led to much introspection by scientists from all branches. Evolutionary biologists especially saw this with surprise, as the whole idea of evolution is about the spontaneous emergence of order. [1] The question is, among all these

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1 **Boltzman and Darwin** Here are the two complementary views posed by Darwin and Boltzmann. From a thermodynamic point of view, Darwin's theory is the natural selection favouring the generation of order. Boltzmann, on the other hand, conjectures the relevance of ever-increasing disorder in the Universe. $Schrödinger's$ solution was that in an open system, there is a supply of order and a generation of disorder, and the competition of the two makes the living state. One (Boltzmann) predicts a generation of disorder, and the other (Darwin) predicts the generation of organized complexity or order. How can we reconcile the two? How can Boltzmann-type disappearance of unusual, more organized states be reconciled with Darwin's statistical selection of rare events? Darwin's theory begins with an assumption of the spontaneous fluctuations of species, which are reinforced and lead to self-organization and more complexity (more order). So apparently, we can say that Darwin's theory is about the generation of order, and Boltzmann's theory is about the disappearance of order (interestingly, the former was a big admirer of the latter). The inscription on the Boltzmann tomb reads $S = k.logW$. Incidentally, Boltzman's derivation can be mathematically matched with Cauchy's theorem that if

$$f: R -> R, f(x) + f(y) = f(x + y) f(x) = x.f(1)$$

,

$$S = S_1 + S_2$$
$$W = W_1.W_2$$

disputes, why do we bring the entropy term into the context of consciousness? Is it the perception that the conscious state also undergoes a disruptive order to disorder transition? When we see a mass radicalisation, do we feel that somewhere, the individual ordering of conscious states is suddenly dominated by a mass frenzy of a massive scale of disruption of order? However, there is a 'but'. We must note that the essence of entropy is an abstract concept. The concept is understood regarding inaccessible energy, uncertainty or lack of deterministic behavior. The component of us that is inaccessible to us may be complimentary to our consciousness. Entropy was, therefore, looked upon as negative information.

Note

Shannon's information theory was introduced in Shannon (1948). Mathematical structures of thermodynamic entropy and Shannon entropy look strikingly similar. $S_{Bolzmann} = -k_B \Sigma p_i ln p_i$ whereas, $I_{Shannon} = -\Sigma p_i ln p_i$, the major difference between the two being, the missing Boltzmann constant k_B in the Shannon case. The Shannon information is expressed in bits by shifting the logarithmic base to 2, whereas the Boltzmann entropy is expressed in the unit of k_B, i.e., $Joules/^o K$.

While Boltzmann entropy is applied to thermodynamic systems undergoing some irreversible processes, Shannon entropy is applied to communication channels. The obvious question is why we bring in Shannon entropy in the context of consciousness. Does consciousness involve transferring information like one is in a communication channel? If so, the question would automatically follow from where to where. Many of our ancient texts from various cultures describe the evolution of consciousness as the flow of an unknown entity from one compartment to another, called the source and destination of communication by various names. Famous is the

. Equations are related by the physical concept that entropy is a function of arranging a set of states W.

$$S = F(W)$$

. Putting the equations together we find that

$$F(W_1) + F(W_2) = F(W_1 . W_2)$$

. The solution that follows is,

$$I(X;Y) = F(W) = k.log(W)$$

folk song "Khachar Vitor Ochin Pakhi Kemne Ashe Jay" Lalan Fakir, which means it is remarkable to see how the bird in the cage is communicating with the bird in the sky, how the information of the unbounded space is translated to a space that is limited by the boundary of a cage Lorea (2016).

We thus see both perspectives of entropy, namely 'Boltzmann' and 'Shannon', having some 'flavour' of consciousness in their respective connotation. While Boltzmann entropy obeys a law, namely the second law of thermodynamics, no such exact rules exist for information flow, though the Shannon channel capacity theorem Costello and Forney (2007) implies some constraints of the maximum rate of information flow. [2].

5.1 Entropy for Non-equilibrium Systems and their Nonlinearity

The late Ilya Prigogine can be credited for inducting a dynamical systems perspective on entropy. Briefly, he unified non-equilibrium thermodynamic systems with dynamical systems by identifying the excess entropy as a Lyapunov function, which will remain negative definite but whose time derivative will be positive definite. Prigogine (1978) identified excess entropy $\partial^2 S = S - S_{eq}$ as a negative definite entity by virtue of the second law. It introduced a minimisation principle that makes the rate of change of excess entropy as positive definite.[3].

5.2 Second Law like Restriction in Shannon Entropy

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2 Shannon entropy, introduced by Claude Shannon, measures the uncertainty in a set of possible outcomes. Mathematically, it can be expressed as:

$$H(X) = -\sum_i p(x_i) \ln p(x_i)$$

where, $p(x_i)$ is the probability of outcome x_i.

3 Prigogine's equivalence of thermodynamic system and dynamic systems

$$\partial^2 S = S - S_{eq} \leq 0 \tag{5.2}$$

$$\frac{d}{dt} \partial^2 S \geq 0 \tag{5.3}$$

Prigogine proved the validity of this dynamical principle by considering a number of reaction networks, including Brusselators (a model that came from the Brussels group Adomian (1995)). Some discussions on information transfer in non-equilibrium systems are discussed in Zeng, Li, and Wang (2023). Ironically, Brussels is witnessing many political and economic dynamics for which minimization principles like this may eventually fail Geary (2023).

The Shannon channel capacity theorem states that for any given level of noise in the channel, there exists a maximum rate at which data can be transmitted with an arbitrarily low probability of error. This rate is called the channel capacity c.

Warning
What additionally follows is $$C = B * \log 2(1 + SNR) \quad (5.1)$$ where, rate of information transfer $\leq C$.

B is the bandwidth, and SNR is the signal-to-noise ratio. We should also look into other formulations of information. Fischer entropy is a notable example.[4]

5.3 Integrated Information

Integrated Information Theory is a framework proposed by Giulio Tononi (Schirmer, Tononi, and Koch (2018)) to explain and quantify consciousness. The core idea is that consciousness corresponds to the capacity of a system to integrate information.

Consciousness is closely related to information processing in the sense that it deals with uncertainty of various sorts. The question arises is whether, like the second law of thermodynamics, the information content associated with consciousness would also follow the second law (e.g., information from the source is always greater than the information from the sink or receiver).

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4 *Information and Fischer Entropy* Fisher information measures the amount of information that an observable random variable X carries about an unknown parameter θ. If we define:

$$J(\theta) = \frac{\partial \log F(X;\theta)}{\partial \theta} \quad (5.5)$$

The Fischer information is defined as:

$$I(\theta) = \mathrm{E}(J(\theta)^2) \quad (5.6)$$

Second law as per Fischer information Information Inequality (Cramér-Rao Bound): The Cramer-Rao bound states that the variance of any unbiased estimator

$$Var\left(I(\hat{\theta})\right) = \frac{1}{I(\theta)}$$

Note

Since it is hardly possible to define **source** and **sink** for consciousness, some tend to think that the source is the brain, some think it is the high-frequency oscillation of some molecule like microtubules, some believe that it is an ensemble of quantum processes like coherence or de-coherence. We feel that the entropic (or information-theoretic) foundation of consciousness has a more robust and global perspective, but like other things in thermodynamics, it has a lesser association with the mechanistic contour of conscious processes. However, there have been some attempts to describe integrated information in metabolic networks, such as Schirmer, Tononi, and Koch (2018), Schneidman and Tishby (2017), and Itti, Baldo, and Braun (2015).

We should also know two other information-related terms: mutual information [5] and causal entropy. [6]

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5 Mutual information (MI) measures the mutual dependence between two variables. It is calculated as the difference between the entropy of each variable and the entropy of the two variables when considered together. MI is a helpful measure for understanding the relationship between two systems, and it has been used to study a variety of phenomena, including consciousness. In the context of metabolic networks, mutual information can be used to measure the degree of dependence between two metabolites or between two reactions. The mutual information between two variables, X and Y, is defined as:

$$I(X;Y) = \sum_{x}\sum_{y} p(x,y) \log \frac{p(x,y)}{p(x)p(y)}$$

where: $p(x,y)$ is the joint probability distribution of X and Y, p(x) is the marginal probability distribution of X and $p(y)$ is the marginal probability distribution of Y. The mutual information between two variables is always non-negative, equal to zero if and only if X and Y are independent. In the context of metabolic networks, the mutual information between two metabolites or two reactions can be used to measure their degree of integration. A high mutual information value indicates that the two variables are strongly dependent on each other and are, therefore, part of a tightly integrated system.

6 Causal entropy measures the uncertainty about the causes of a system's state. It is calculated as the amount of information needed to know the exact causes of the system's state. Causal is a useful measure for understanding the complexity of a system, and it has been used to study various phenomena, including consciousness. One theory of consciousness is that it is a product of the

5.4 GNW The Global Neuronal Workspace

GNW is an abbreviated form of global neuronal workspace proposed by psychologist Bernard J. Baars (Edelman, Gally, and Baars (2011)) and neuroscientists Stanislas Dehaene (Dehaene, Lau, and Kouider (2021)) and Jean-Pierre Changeux (Dehaene and Changeux (2004)).GNW argues that consciousness arises from a particular type of information processing – familiar from the early days of artificial intelligence when specialised programs would access a small, shared repository of information. Whatever data were written onto this "blackboard" became available to a host of subsidiary processes: working memory, language, the planning module, and so on. According to GNW, consciousness emerges when incoming sensory information, inscribed onto such a blackboard, is broadcast globally to multiple cognitive systems – which process these data to speak, store or call up a memory or execute an action.

Integrated information theory (IIT), developed by Tononi and his collaborators, including me, has a very different starting point: the experience itself. Each experience has specific essential properties. It

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brain's complex and integrated information processing. Causal entropy can be used to measure the complexity of information processing in the brain. For example, studies have shown that causal entropy is higher in conscious patients than in unconscious patients. Additionally, causal entropy has been shown to increase with arousal and decrease with sleep. Another theory of consciousness is that it is a product of the interaction between different brain parts. Causal entropy can be used to measure the interaction between different brain regions. For example, studies have shown that causal entropy is higher between brain regions involved in conscious processing than between brain regions not involved in conscious processing. Causal entropy is a measure of the uncertainty about a variable X that remains after taking into account the information about X that is contained in another variable Y. The causal entropy of X given Y is defined as:

$$H(X|Y) = -\sum_x p(x|y) \log p(x|y) \tag{5.9}$$

where: $p(x|y)$ is the conditional probability distribution of X given Y The causal entropy of X given Y is always non-negative, and it is equal to zero if and only if X is perfectly predictable from Y. In the context of metabolic networks, the causal entropy of a metabolite or reaction given another metabolite or reaction can be used to measure the degree to which the first variable is causally dependent on the second variable. A high causal entropy value indicates that the first variable is not perfectly predictable from the second variable and that the two variables are not causally independent.

is intrinsic, existing only for the subject as its "owner"; it is structured (a yellow cab braking while a brown dog crosses the street); and it is specific – distinct from any other conscious experience, such as a particular frame in a movie. Furthermore, it is unified and definite. When you sit on a park bench on a warm, sunny day, watching children play, the different parts of the experience – the breeze playing in your hair or the joy of hearing your toddler laugh – cannot be separated into parts without the experience ceasing to be what it is.

5.5 The Entry of Schrodinger:

The dichotomy between Boltzmann and Darwin, namely the increase of disorder with time and the emergence of order with time, was resolved by Schrodinger by introducing negative entropy (or entropy supply). The supply term can be both positive and negative. When it comes in the form of the Sunlight, one obtains the negative entropy. On the other hand, the internal entropy change is the dissipation part and follows the dictum of the conventional second law (namely, always positive).

Note

The split of the net entropy into a supply and production term was one of the best parts of Schrodinger's formulation.

$$\Delta S = \Delta S_{Supply} + \Delta S_{Interal}$$

The restriction imposed by the second law remains in the entropy production (i.e., the dissipation part):

$$\Delta S_{Interal} \geq 0 \text{ (by Second Law)}$$

5.6 Maxwell's Small Being (Demon) and The Thermodynamics of Consciousness

Maxwell conceived a thought experiment Bennett (1987) to further the understanding of the second law. Originally, Maxwell termed this agent as a "small being", but it was readdressed as a demon by Lord Kelvin Thomson et al. (1879). It may be interesting to recall that Lord Kelvin implied that he intended the Greek mythology interpretation of a 'daemon', a supernatural being working in the background. This tiny being can see individual gas molecules and manipulate a trapdoor. Its goal is to sort the molecules. It lets fast-moving (hot) molecules go one way, and slow-moving (cold) molecules go through the other side of the trapdoor. Over time, this would create a temperature difference, violating the second law of thermodynamics, which states that disorder (entropy) naturally increases in a closed system. A tiny being or 'Daemon', whatever term we attribute to this tiny being, will remain one of the most prominent thermodynamic definitions of conscious behaviour. Maxwell's small 'being' can take intelligent steps, like fishing out only the faster molecules by sensing them as it is conscious. The conscious state is enabled as it can discriminate between the faster and slower molecules. While most of the typical response to this thought experiment is that in its original form, it was proposed as a scenario that violates the second law of thermodynamics as the order is spontaneously created in a closed system. For open systems, however, Maxwell's daemon can freely operate without causing any contradiction to the second law. The 'small being' can have a trade-off between supply and production of entropy, the supply term being absent in the original form of Maxwell's daemon, which led to the paradoxical violation of the second law. We want to maintain that Maxwell's 'small being', which is more general than the daemon, is actually a thermodynamic model for 'conscious' behaviour. As the 'small being' can survive in an open system, it follows that a conscious being can lead to the generation of order and information provided the system is open. The minimal thermodynamic law of consciousness follows: *only open systems would support a conscious behaviour.*

5.7 Can Entropy be Complex?

Complex entropy Abou Jaoude (2018), Nalewajski (2016), also known as differential entropy or continuous entropy, is a concept from information theory that extends the notion of entropy to continuous probability distributions. While traditional entropy measures the amount of uncertainty or randomness in a discrete probability distribution, complex entropy deals with continuous variables.

In the context of continuous probability distributions, complex entropy is defined as the negative of the integral of the probability density function (PDF) multiplied by the natural logarithm of the PDF. Mathematically, for a continuous random variable X with PDF f(x), the complex entropy H(X) is given by:

$$H(X) = -\int f(x) * log\big(f(x)\big)dx$$

It is worth noting that complex entropy is not always defined for all continuous probability distributions. Some distributions may have infinite or undefined complex entropy. In such cases, alternative measures like Renyi or Tsallis entropy can be used.

Complex entropy has applications in various fields, including signal processing, data compression, and statistical inference. It measures the uncertainty or amount of information carried by continuous random variables and can be used to analyse and compare different continuous probability distributions.

5.8 A Simpler Account for Complex Entropy

The Boltzman law can be written as:

$$S = k_B \cdot log(P)$$

We can now write the law in an inverse form:

$$P = e^{S/k_B - 2\pi \cdot j \cdot n}$$

Where n is any integer.

We can rewrite the above equation as:

$$S/k_B = log(P) + 2\pi \cdot j \cdot n$$

Now, we can conceptualise three systems with equal P values but with different n values. The difference in entropy between such systems will be an imaginary entity:

$$\Delta S/k_B = 2\pi.j.n$$

where, n is an integer.

5.9 Electrical Circuit

Now, let us consider the complex entropy as proposed by Nalewajski (2016). The imaginary part of the entropy is termed the Shannon phase-entropy component, being then attributed to the imaginary part.

The impedance is given by

$$Z = R + j.X$$

$$X = \omega.L - 1/\omega C$$

For a given temperature, the dissipation

$$T.dS/dt = (I * I)(R + j.X) = |I^2|(R + j.X)$$

or,

$$T.\Delta(S + 2k_B\pi jn) = |I|^2(R + j.X).\tau \text{ where, } \tau = \delta t$$

$$|I|^2X.\tau = 2k_B.T\pi n\ S/\tau = |I|^2 \cdot R$$

The imaginary part balance implies,

$$\omega \cdot L - 1/\omega \cdot C = 2\pi.n.k_B.T.\tau/I^2$$

For a given T, L, C and |I|, we have some:

$$\omega = \omega(n), n = 0,1,2,..$$

Such discrete dependence of user-controlled parameter ω implies selection rules on the circuit.

5.10 Complex Entropy Versus the q-entropy

A more generalised way of expressing the Boltzmann-Gibbs-Shannon entropy is considering the entropy as an expectation for

$$log(1/p_i).\ S_{BGS} = \langle ln(1/p_i)\rangle.$$

A new form of entropy based on the natural logarithm was proposed to consider incomplete information. The entropy is then defined by Radhakrishnan, Chinnarasu, and Jambulingam (2014).

$$S_{BGS} = \langle ln(1/p_i)\rangle = \Sigma_i p_i^q\, ln(1/p_i)$$

If we assume that complex q-entropy always assumes an absolute value, the simplification we obtain for a two-state system is as follows:

$$\Sigma_i 2\pi \cdot n_i \cdot j \cdot p_i^q = 0$$

For a two-state system, this amounts to:

$$p1/p2 = (-n_2/n_1)^{1/q}$$

In the above equation, one of the essential features in the states '1' and '2' will be coupled by either $sgn(n1) + sgn(n2) = 0$ or $1/q = 2k, k = 1,2,..$ so that the probability ratio assumes a positive value. It may be noted that the q-expectation value describes some "incompleteness" of small or complex systems. Therefore, a selection rule on "q" indicated some restrictions to the nature of complex behavior that may emerge. The take-home message in this simple exercise is that we can observe very large complex systems, but even in such systems, there are some restrictions in the mutual interaction. This remains valid when cellular clusters at the micron scale are formed. This clustering is a scaled-up version of cluster formation at the nanoscale – small molecules like water cluster due to hydrogen bond formation even at the sub-nano level.

5.11 Complex Entropy and Consciousness

Some of the ways that consciousness can be broken down into components is by introducing terms like self-awareness, the ability to recognise yourself as an individual separate from others; metacognition, the ability to be aware of your own thoughts and mental processes; qualia, the subjective, qualitative nature of experience. The entropic interpretation gets us rid of this component-wise breakdown. In Chapter 4, we interpreted the **phase Shannon entropy**, the imaginary part of entropy, as intuition. This component makes the implicit connection between intuition and consciousness, as only a conscious object may retain intuition and other similar attributes like self-awareness, metacognition, and qualia.

5.12 The Complexity-Entropy Space

Complexity Zurek (2018) refers to the organisation, patterns, or intricacy level present in a system. In contrast, entropy measures the randomness or uncertainty within the system. In information theory, entropy quantifies the amount of information or surprise in a data set. The complexity-entropy graph best expresses the relation between the two; each point on the graph represents a specific state or configuration of the system. The x-axis typically represents the system's complexity, while the y-axis represents the entropy. The graph may show a scatter plot of data points or a smooth curve that describes the overall trend. One can have

- Low Complexity, Low Entropy: The system is in a simple and ordered state in this region. There is little randomness or unpredictability, and the system shows a low level of complexity.
- High Complexity, Low Entropy: This region represents systems with high organisation and complexity but low entropy. Such systems exhibit regular patterns and structure, leading to reduced uncertainty.
- Low Complexity, High Entropy: In this region, the system is disordered and random, resulting in high entropy. There is

little organisation or complexity, and the system is highly chaotic.

- High Complexity, High Entropy: This is the region of interest for complex systems. These systems exhibit high complexity and entropy, balancing order and disorder. They may display self-organisation, emergent behaviour, and intricate patterns.
- The complexity-entropy graph provides valuable insights into the behavior of complex systems, ranging from physical systems like fluids and weather patterns to biological systems and even human society. Studying these patterns can help researchers understand these systems' underlying dynamics, stability, and predictability.

5.13 Complexity Entropy Curve

The complexity entropy curve of a time series TS is a plot of the complexity entropy of TS as a function of the number of points in TS. The complexity entropy of a time series measures the amount of uncertainty or randomness in the time series.

The complexity entropy curve can be used to distinguish between different types of time series. For example, deterministic time series typically have increasing complexity entropy curves, while stochastic time series typically have decreasing complexity entropy curves.

The complexity entropy curve can also be used to identify changes in the dynamics of a time series. For example, if the complexity entropy curve decreases, it may indicate that the time series is becoming more predictable.

The complexity entropy curve is a valuable tool for understanding time series dynamics. It can be used to distinguish between different types of time series and to identify changes in the dynamics of a time series.

Here is an equation for the complexity entropy of a time series TS:

$$complexity\ entropy(TS) = -\Sigma_{i=1}^{N} p(x_i) \log(p(x_i))$$

where TS is the time series, N is the number of points in TS, and $p(x_i)$ is the probability of the i-th point in TS.

The complexity entropy curve can be calculated using the following steps: Calculate the complexity entropy of TS for each number of points from 1 to N. Plot the complexity entropy as a function of the number of points. The complexity entropy curve can be used to understand the dynamics of a time series by looking for changes in the curve. For example, if the complexity entropy curve decreases, it may indicate that the time series is becoming more predictable.

5.14 Our Brief for the Entropy-based Approach to Consciousness

- Shannon (1948) explicitly stated that information theory is a mathematical theory concerned with measuring information independent of the meaning or content. According to him, the lack of semantics is one of the primary weaknesses of the theory. Consciousness, on the other hand, is all about meaning and its entanglement with the communication process. What we have been able to highlight is that the following add-ons to the mathematical framework may provide a good template for describing consciousness in the light of information-theoretic and entropic processes:
- Like Maxwell's demon, the consciousness has to have a decision-making ability. An open system that enables the free exchange of information and entropy with the surroundings can open up such a possibility.
- In a few instances, oscillatory transitions of states may occur that may be best described by the complex entropy process.
- The arrow of time (second law) for the real entropic process may differ from the same for the imaginary entropy.

6

Consciousness and Individuality

Scott Gilbert Gilbert, Sapp, and Tauber (2012), a developmental biologist at Swarthmore College, conjectured that "Twentieth-century biology was a biology of things". He added that, "Twenty-first-century biology is a biology of processes." Gilbert was a proponent of a hypothesis that we have never been individuals. In his symbiotic view of life, the consciousness, therefore, has to have a collective implication. A collection of processes is akin to the 'Internet of Processes' instead of the 'Internet of Things'. An information theoretic approach to the definition of individuality, which is closely related to the definition of consciousness, is also proposed by Krakauer et al. (2020). They define individuality at three levels: organismic, colonial and tornado-like; the last one is almost like defining consciousness as a bubble that dissipates and reorganises itself. While the stated gradations of individuality may appear to be a little abstract, the availability of oceanic data indicates the existence of rangeomorphs, fernlike animals that could grow to more than six feet tall, with fractal, branching fronds that radiated from a central stem attached to the seafloor Hoyal Cuthill and Conway Morris (2014). They are good examples of the colony as a form of individuality, as stated by Krakauer et al. (2020). The following section describes how we can arrive at the biology of process and how it re-focusses attention from a brain-based approach to a more generalised and abstract approach to consciousness.

6.1 Endosymbiosis Game and the Evolution of Consciousness

Let us start with a simple concept, namely the coupling of chemical reactions. Coupling in chemical reactions is considered consecutive reactions with a common chemical intermediate.

$$A + B \rightarrow C \tag{6.1}$$

$$C \rightarrow D \tag{6.2}$$

The coupling between reactions expressed by (6.1) and (6.2) is determined by the presence of C, the common intermediate. In chemiosmotic coupling, the coupling equation is written in terms of a coupling equation:

$$J_O = L_{OO}(-\Delta G_O) + L_{OH}\Delta\bar{\mu}_H \tag{6.3}$$

$$J_H = L_{OH}(-\Delta G_O) + L_{HH}\Delta\bar{\mu}_H + L_{HP}(-\Delta G_P) \tag{6.4}$$

$$J_P = L_{PP}(-\Delta G_P) + L_{PH}\Delta\bar{\mu}_H \tag{6.5}$$

where J terms represent **fluxes** of oxygen (suffix O), proton (suffix (H)) and phosphorylation (suffix P). The free energy terms $-\Delta G_o$, $-\Delta G_P$ and $\Delta\bar{\mu}_H$ represents the corresponding thermodynamic **forces**. The flux-force relation typically represents a phenomenological equation. The term L_{HH} represents a proton conductivity of the mitochondrial membrane, which, according to Mitchell, is maintained at a low value so that the leakage of the proton is minimized and whatever outflow or inflow of the proton occurs remains tightly coupled and synchronised. On the other hand, if L_{HH} is high, there will be uncoupling. The entire coupling scenario is thus dependent on the protic status of the membrane. If we express Mitchell's hypothesis, we can use two punch lines:

The coupling agent for oxidative phosphorylation is:

$$\Delta\bar{\mu}_H = \Delta\psi - Z'\,\Delta pH \tag{6.6}$$

$\Delta\psi$ being the membrane potential, Z' being the constant that converts pH to membrane potential (determined by Faraday's law of electrochemistry) and has a value 60mV (approx.), and the electrochemical potential of the proton is the sign reversed proton motive force. Notably, the electrochemical potential gradient assumes a null value for a battery that follows Nernst equilibrium. In respiring mitochondria, the departure from Nernst equilibrium is maintained by the pumping of protons.

- Uncoupling occurs if the proton conductance L_{HH} shoots up. That is, proton leaks should be minimized to avoid uncoupling.

$$L_H \approx 0 \ \forall \ coupled\ states$$

$$L_H \approx \infty \ \forall \ uncoupled\ states$$

Many biochemists, including Lehninger, firmly believed in the existence of a high-energy intermediate that would be responsible for the coupling of electron transport and oxidative phosphorylation processes (Slater, Kemp, and Tager (1964)). However, just as many other scientific ideas have been proven wrong over time (such as the existence of Aether), the existence of any such intermediate has been ruled out. Mitchell, the proponent of the chemiosmotic theory (Mitchell and Moyle (1967)), argued that protons are pumped out of the inner mitochondrial membrane during oxidation and then pumped back in in the reverse direction (from out to in) via the ATPase F0 channel. The F1 component of the ATPase then synthesises ATP.

Table 6.1 Comparative phosphorylation in mitochondria and cell

	Mitochondria 1 ATP Generation	**Cellular Phosphorylation**
Efficiency	More efficient	Less efficient
Location	Occurs in mitochondria	Occurs throughout the cell
Process	Involves oxidative phosphorylation	Involves substrate-level phosphorylation
ATP yield	Can generate up to 36 ATP molecules per glucose molecule	Generates only 2 ATP molecules per glucose molecule

Table 6.2 Functional description of mitochondrial electron transport

Complex	**Location**	**Function**
Complex I	Inner mitochondrial membrane	NADH dehydrogenase; transfers electrons from NADH to CoQ
Complex II	Inner mitochondrial membrane	Succinate dehydrogenase; transfers electrons from succinate to CoQ
Complex III	Inner mitochondrial	Cytochrome bc1 complex; transfers

	membrane	electrons from CoQ to cytochrome c
Complex IV	Inner mitochondrial membrane	Cytochrome c oxidase; transfers electrons from cytochrome c to O2, reducing it to H2O

6.2 ROS Management by Mitochondria

Mitochondria are a significant source of reactive oxygen species (ROS), including hydrogen peroxide (H2O2), which can cause oxidative damage to cellular components if not properly managed. Mitochondria use a range of mechanisms to manage ROS, including enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase. SOD converts superoxide radicals (O2.-) into H2O2, which can then be converted into water and oxygen by catalase or glutathione peroxidase.

However, recent studies suggest that mitochondria also use non-enzymatic mechanisms to manage ROS, including the production of antioxidants such as glutathione and thioredoxin, as well as the regulation of mitochondrial biogenesis and turnover.

Table 6.3 ROS Management by Mitochondria

Complex	Location	ROS Production
Complex I	Inner mitochondrial membrane	Generates superoxide (O2.-) by leaking electrons to O2
Complex III	Inner mitochondrial membrane	Generates superoxide (O2.-) by transferring electrons to O2
Complex IV	Inner mitochondrial membrane	Generates superoxide (O2.-) by transferring electrons to O2
Monoamine oxidase	Outer mitochondrial membrane	Generates hydrogen peroxide (H2O2) by oxidizing monoamines

6.3 Pathways for ROS Management by Mitochondria

Several pathways have been proposed for how mitochondria manage ROS and maintain redox homeostasis. Here are some of the commonly accepted models:

- Antioxidant Defense System Model: Mitochondria manage ROS through the action of antioxidant enzymes such as SOD, catalase, and glutathione peroxidase. These enzymes work together to convert ROS into less harmful products.
- Redox Signaling Model: ROS generated by mitochondria can act as signaling molecules, regulating cellular processes such as gene expression, protein synthesis, and apoptosis. In this model, ROS are not just toxic byproducts of metabolism but rather serve critical physiological functions.
- Mitochondrial Quality Control Model: ROS serves as a signal to trigger mitochondrial biogenesis and turnover, ensuring that damaged or dysfunctional mitochondria are eliminated and replaced with healthy ones.
- Mitochondrial Permeability Transition Model: This model proposes that excessive accumulation of ROS can lead to the opening of a mitochondrial permeability transition pore, resulting in mitochondrial swelling, loss of membrane potential, and, ultimately, cell death.

These pathways are not mutually exclusive and act in tandem to maintain redox homeostasis in mitochondria.

6.4 Singlet and Triplet States of Oxygen

Oxygen is a diatomic molecule with a total of 16 electrons. In its ground state, the two oxygen atoms are in a triplet state, meaning their spins are parallel, resulting in a total spin of S=1. The electronic configuration of the ground-state oxygen molecule can be represented as

$$(\sigma_{1s})^2(\sigma_{1s})^2(\sigma_{2s})^2(\sigma_{2s})^2\left(\pi_{2px}\right)^2\left(\pi_{2py}\right)^2\left(\pi_{2pz}\right)^2$$

Singlet oxygen, on the other hand, is an excited oxygen state with a different spin state and electronic configuration. It can be generated by the energy transfer from a photosensitizer molecule or by the reaction between ground-state oxygen and a singlet-state sensitizer. In singlet oxygen, the spins of the two oxygen atoms are antiparallel, resulting in a total spin of S=0. The electronic configuration of singlet oxygen can be represented as

$$(\sigma_{1s})^2(\sigma_{1s})^2(\sigma_{2s})^2(\sigma_{2s})^2\left(\pi_{2px}\right)^2\left(\pi_{2py}\right)^2\left(\pi_{2pz}\right)^0$$

Where σ and π represent the molecular orbitals formed by the atomic orbitals of the two oxygen atoms, one of the π orbitals is empty due to the antiparallel spin configuration.

The singlet state of oxygen is a - higher energy state than the triplet state and - is much more reactive due to its lower energy barrier for chemical reactions.

Singlet oxygen can undergo a transition to its triplet state, which is a lower energy state, by releasing excess energy in the form of heat or transferring the energy to other molecules. This triplet-state oxygen is also highly reactive and can cause oxidative damage to biological molecules, including proteins and DNA, through various mechanisms.

6.5 Quantum Mechanical Properties of ROS

Quantum mechanics describes ROS (reactive oxygen species) in terms of their electronic structure and behaviour. ROS are highly reactive molecules that can be described by their electronic configurations and interactions with other molecules.

For example, singlet oxygen $O_2^{\bullet}$ can be described as having two unpaired electrons in its outer pi antibonding orbital. This makes it a highly reactive species that can react with other molecules, such as lipids and proteins, leading to oxidative damage.

Other ROS, such as superoxide $O_2^{\bullet}$ and hydroxyl radical, $OH^{\bullet}$ can also be described in terms of their electronic structure and reactivity. Superoxide is a radical species with one unpaired electron, while hydroxyl radical is a highly reactive species with one unpaired electron and one partially filled orbital.

Quantum mechanics can also be used to study the reactions of ROS with other molecules, including antioxidants that can neutralize their reactivity. Overall, quantum mechanics provides a powerful tool for understanding the electronic properties and reactivity of ROS, which can have important implications for many biological processes and diseases.

6.6 Response of ROS to Static Magnetic Field

The two classes of ROS containing singlet and triplet oxygen species have an important distinction. The triplet species with spin one will likely respond to the magnetic field. The triplet fusion process common in photosynthetic systems has been a hotbed for quantum biology. Since photonic involvement is relatively uncommon in mitochondria, it is surprising that the magnetic field affects the ROS generation in mitochondria.

According to the review (H. Wang and Zhang (2017)), the effects of magnetic fields on ROS levels tend to increase ROS. However, some evidence also showed that MFs reduced or did not change ROS levels.

6.7 Plausible Inference of the Ambiguous Magnetic Effect

- No magnetic response may happen when the ROS contains singlet species (S=0).
- Any effect of magnetic field suggests that triplet states are present (S=1).
- The two points above explain why we may have both positive and negative effects of the static magnetic field in relation to ROS generation in mitochondria.
- The question, however, boils down to the possible origin of triplet states of ROS in mitochondria. The report Murphy and Smith (2007) describes the formation of triplet states of ROS in the mitochondrial matrix as a result of electron transfer reactions and discusses the potential role of these triplet states in oxidative stress and cellular damage.
- There are recent reports (Gawarecki and Machnikowski (2021)) on phonon-assisted transitions between the triplet and singlet states in external magnetic and electric fields. Can such transition occur in mitochondria?
- If the last question has a positive answer, we need to assume that there is a phononic transition in mitochondria.
- The differential magnetic sensitivity and the possibility of phonon-assisted singlet-triplet transition make the quantum biology of mitochondrial ROS both exciting and challenging.

6.8 Endosymbiosis: A Game of Give and Take

The keywords for mitochondria can be delineated as follows:

- ROS
- Protic Flow
- ATP synthesis

- Oxygen Uptake

The evolutionary question of why the cell hosted the mitochondria can be looked upon in terms of an evolutionary tradeoff. As seen before, the cell has a low efficiency in ATP production. On the other hand, the mitochondria need the oxygen that the cell provides via electron transport.

Table 6.4 Tradeoff between cell and mitochondria

Aspect	Without Mitochondria	With Mitochondria
ATP production	Low efficiency	High efficiency
Oxygen dependence	Not dependent	Dependent
Energy cost	Lower energy cost	Higher energy cost
Adaptation to anaerobic environments	Better adaptation	Poor adaptation
ROS production	Lower ROS production	Higher ROS production
Replication	Binary fission	Mitochondrial replication
Genetic material	Nucleus only	Mitochondrial DNA + nucleus
Inheritance of traits	Mendelian	Non-Mendelian
Evolutionary stability	Stable	Vulnerable to mutation

Mitochondria provide eukaryotic cells with a positive payoff of metabolic advantages. However, they may generate negative payoffs for the cell as well, such as reactive oxygen species that damage both nucleocytoplasm and mitochondria, resulting in mutations, diseases, and ageing. The presence of both negative and positive payoffs and the fact that they reached a stable configuration after several evolutionary interactions over a period of time motivates a game theoretic model. Further, the risk of negative payoff for both players is partially eliminated even after endosymbiosis is established. So, the game is not entirely a zero-sum game. This endosymbiosis is pervasive and conserved across eukaryotic species and vast time scales. These observations motivate our assertion that the players are not just mechanistic and deterministic but are acting with a proto-consciousness.

6.9 A Mitochondrial Game

Table 6.5 Payoff matrix for the mitochondrial game

	Mitochondria chooses	Mitochondria chooses

	Cooperation	**Exploitation**
Cell chooses Cooperation	Cell = R, Mitochondria = R	Cell = S, Mitochondria = T
Cell chooses Exploitation	Cell = T, Mitochondria = S	Cell = P, Mitochondria = P

T(temptation) > R(reward) > P(punishment) > S(sucker, the player who chooses to cooperate while the other player chooses to defect). If T > R > P > S, then the prisoner's dilemma game has a unique Nash equilibrium, which is for both players to defect (i.e., choose Exploitation).To see why, consider the following reasoning: If the other player chooses Cooperation, then a player can either choose Cooperation and get a payoff of R or choose Exploitation and get a payoff of T. Since T > R, it is always better to choose Exploitation, regardless of what the other player chooses. If the other player chooses Exploitation, then a player can either choose Cooperation and get a payoff of S or choose Exploitation and get a payoff of P. Since P < S, it is always better to choose Exploitation, regardless of what the other player chooses. Therefore, both players will choose *Exploitation in the unique Nash equilibrium*. Thus, in a classical scenario, the Nash equilibrium does not match with the occurrence of endosymbiosis. The Nash equilibrium is a condition at which they will never undergo endosymbiosis.

```
check_nash <- function(matrix) {
 n_rows <- nrow(matrix)
 n_cols <- ncol(matrix)

 for (i in 1:n_rows) {
 for (j in 1:n_cols) {
 current_payoff <- matrix[i,j]
 row_best_response <- max(matrix[i,])
 col_best_response <- max(matrix[,j])

 if (current_payoff == row_best_response &&
current_payoff == col_best_response) {
 return("Nash equilibrium is present")
 }
 }
 }

 return("Nash equilibrium is not present")
}
```

For a typical case, with 3,1,5,0 as typical values of P, R, T, S:

C		E
C	P, P	S, T
E	T, S	R, R

6.10 Two State Game

In his seminal work on quantum game theory Meyer (1999), Meyer considered the simple game "penny flip" to consist of the following:

- Artha prepares a coin in heads
- Vac, without knowing the state of the coin, chose to
  - either flip the coin
  - or leave it as it is
- Vac has a second turn
- Coin is then examined
- If the head, Vac wins

6.11 Classical Version - Probabilistic Nature of Vac's Win

```
# set up the game
artha_coin <- "heads"

# define a function to simulate Vac's turns
vac_turn <- function(coin_state){
 if(coin_state == "heads"){
 # If the coin is heads, Bob can either flip it or
leave it as it is
 if(runif(1) < 0.5){
 # If the random number is less than 0.5, Bob flips
the coin
 coin_state <- "tails"
 }
 }
 # Bak always gets a second turn
 if(runif(1) < 0.5){
 # If the random number is less than 0.5, Bob flips
the coin
 coin_state <- ifelse(coin_state == "heads", "tails",
"heads")
 }
 return(coin_state)
}
```

```
for (i in 1:10){
 print(vac_turn("heads"))
}

[1] "tails"
[1] "tails"
[1] "heads"
[1] "tails"
[1] "heads"
[1] "tails"
[1] "heads"
[1] "tails"
[1] "heads"
[1] "heads"
```

6.12 Quantum Version of the Game Outcome

Deterministic nature of Vac's win In the quantum version of the game, the qubits decide between Vac and Artha. Each player can choose one of two strategies: leave their qubit in the "0" state or flip it to the "1" state. The rules of the game are identical. However, the decision to play the fame is decided by the operators. The operators provide us with strategies that will make it possible to keep the coin unflipped or flip. The essential operators are:

- *Identity* operator $I = |0><0| + |1><1|$
- *Pauli Sigma X operator* $\sigma_x = |0><1| + |1><0|$
- *Hadamard operator*
- H= $\frac{1}{\sqrt{2}}|0><0| + |1><0| + |0><1| - |1><1|$ that produces a superposition of states which are symmetric and antisymmetric in nature. The following equations will clarify the properties of the operators:

The transformations are given by the following equations:

$$I|1> = 1; I|0> = 0 \tag{6.9}$$

$$\sigma_x |1> = 0; \sigma_x |0> = 1 \tag{6.10}$$

$$H|0> = \frac{1}{\sqrt{2}}(|0> + |1>) \tag{6.11}$$

$$H|1> = \frac{1}{\sqrt{2}}(|0> - |1>) \tag{6.12}$$

Initially, Artha prepares the qubit in the $|0\rangle$ state (which we may equate with head). We may express the preparation state by :

$$\psi_{initial} = |0> \tag{6.13}$$

Artha prepares this game by choosing, say, $|0>$. Now it will be Vac's turn who - may either flip the coin. - or not flip the coin. If Vac flips the coin:

$$|\psi>^{I}_{out} = H\,X\,H|0> = \frac{1}{\sqrt{2}}HX(|0> +|1>) = H(|1> +|0>) = |0> \tag{6.14}$$

In Vac does not flip the coin:

$$|\psi>^{II}_{out} = H\;I\;H|0> = |0> \tag{6.15}$$

The most striking feature of the penny problem is that whatever Vac does (to flip or not to flip), Artha always wins. The situation is expressed by :

$$|\psi>^{II}_{out} = |\psi>^{I}_{out} = \psi_{initial} = |0> \tag{6.16}$$

The code for the quantum strategy in this case would be to:

6.13 Set up the Qubit Based Game

```
artha_coin <- "heads"

vac_turn <- function(coin_state){
 if(coin_state == "heads"){
 # if the coin is heads, Bob can either flip it or
leave it as it is
 # if Vac flips or not
 coin_state= "heads"}
 # Vak always gets a second turn
 # So the outcome will be the same
 return(coin_state)
 }

for (i in 1:10){
 print(vac_turn("heads"))
}

[1] "heads"
[1] "heads"
[1] "heads"
[1] "heads"
```

```
[1] "heads"
[1] "heads"
[1] "heads"
[1] "heads"
[1] "heads"
[1] "heads"
```

6.14 The Comparative Appraisal of the Classical and the Quantum Flip-game - Implication in Endosymbiosis

In the quantum game, the chance of winning depends on who prepares the coin first. If Artha prepares the coin first, Artha will always win if the HIH strategy is adopted. The classical coin flip game has no such possibility as we see "heads" appearing randomly and not always. Let us now assume the quantum flip game in the context of mitochondria. Assuming the ROS in them can have discrete quantum states, their interaction may enable them to perform this coin-flip experiment. If the cell prepares the first set of gene expression, then the mitochondria will be left with a choice to allow or disallow expression that enables endosymbiosis. Suppose they are permitted to undertake the qubit operations instead of the Table 4 undesirable Nash equilibrium. In that case, they may be forced to assume a Nash equilibrium corresponding to Co-operate-Co-operate (instead of exploit-exploit or remain parasitic to each other).

The mechanistic part of the quantum strategy that may appear in the interaction of cells and mitochondria may involve ROS, particularly the spin-spin interaction, enabling them to use qubit-based operations. The entangled qubit-based operation may prerequisite both triplet and singlet species among ROS. Since, in the evolutionary context Rockwell, Lagarias, and Bhattacharya (2014), the original primary endosymbiosis in Archaeplastida, the only known oxygen-producing organisms were cyanobacteria, light sensors might have played a significant role. As indicated earlier, the interaction based on ROS may involve triplet fusion with singlets. The quantum biological aspects of triplet fusing to singlets have already been reported. The qubit-based endosymbiosis theory may be falsified if triplet states are absent and the mitochondria, which do not show any photonic interaction, actually respond to photons. Similarly, the magnetic field-based mitochondrial effects in some cases only indicate that triplets are present in a specific population of mitochondria. The magnetically sensitive components (triplet states) should be mutually exclusive with the light-sensitive components (as only singlet states are excitable with higher efficiency). Understanding endosymbiosis and the qubit-based mechanism may lead to a cell-based super cloning technique. However, we must know the games the cells play and the strategies they assume to play the games.

7

Unity of Life Forms in Fables

Much before Cambridge Declaration on Consciousness (2012) and that non-human living subjects can have consciousness, and much before the disputed Western belief was introduced by the French philosopher René Descartes (1596 - 1650) that animals cannot reason and are more like machines, the ancient Indian and Greek texts had folk stories, popularly known as fables, that used animal intelligence as a medium to spread learning experiences among humans. Who was more ancient among Panchatantra and Aesop can be debated among scholars for whom the geographical tag or date is more important than the content. However, this animal-based teaching system regarding Panchatantra stories or fables may be equivalent to modern-day training sets for humans that enable them to face real-life test sets. The fact that they, by default, assume (we mean the ancient Indian and Greek text) that animals are intelligent proves that they considered them as a part of the 'conscious-sphere'. A Himalayan lake, "Kakbhushundi", is named after a crow who witnessed a whole Ramayana.[1]

---

1 According to Arnold (1893), "" the Hitopadesa may thus be fairly styled "The Father of all Fables"; for from its numerous translations have come Esop and Pilpay, and in later days Reineke Fuchs. Originally compiled in Sanscrit, it was rendered, by order of Nushiraván, in the sixth century A.D., into Persic. From the Persic, A.D. 850 passed into Arabic and then into Hebrew and Greek. In its land, it obtained as wide a circulation. The Emperor Akbar, impressed with the wisdom of its maxims and the ingenuity of its apologies, commended the work of translating it to his own Vizir, Abdul Fazel. That minister accordingly put the book into a familiar style and published it with explanations under the title of the Criterion of Wisdom. '"

7.1 Panchatantra

The Panchatantra Ryder (1949) is an ancient Indian collection of animal fables and stories written by Vishnu Sharma, who probably lived in the salubrious vales of Kashmir.

Note

Scholars believe that the Panchatantra was composed in Sanskrit sometime between the 3rd and 5th centuries BCE. Some of the stories in the Panchatantra are even older and may have been passed down orally before being compiled into the current form.

7.2 Aesop's Fable

The earliest written collection of Aesop's Fables Gibbs (2009) dates back to the Hellenistic period (around the 4th to 1st centuries BCE). The collection is credited to Demetrius of Phaleron, a Greek orator and statesman, who is said to have collected and organised Aesop's stories.

7.3 Comparison of Aesop and Vishnu Sarma

Aesop's Fables and Panchatantra are both collections of animal fables that use anthropomorphic animals to convey moral lessons. However, there are some notable differences between the two collections.

Table 7.1 Difference between fables from Aesop and Panchatantra[2]

Aspect	Aesop's Fables	Panchatantra
Time and place of origin	Greece around the 1-4th century BCE	India around the 3rd century BCE
Target audience	General audience	Specifically written for learners including princes
Structure	Short and less embedding	With embedded stories
Themes	Wisdom, justice	Political and social strategy, education

2 Some of the Panchatantra stories that are depicted in the Hitopadesa. They include, The Crow and the Pitcher, a story that finds its place in scientific literature, Bird and Emery (2009). The fact that this fable suggested that Crows spontaneously exhibit analogical reasoning was subjected to rigorous statistical analysis by Smirnova et al. (2015).

Here are some of the similarities between Aesop's Fables and the Panchatantra:

- Animal characters: Both collections use animals as characters to teach moral lessons, which allows the stories to be more relatable to children, as they can identify with the animals in the stories.
- Moral lessons: Both collections teach moral lessons about the importance of wisdom, justice, hard work, and other virtues. These lessons are often conveyed through the actions of the animals in the stories.
- Entertainment: Both collections are entertaining and engaging stories that people of all ages can enjoy.
- The stories are full of humour, suspense, and adventure, often featuring clever and resourceful animals who overcome challenges.

7.4 Was Chanakya Influenced by Visnu Sarma?

Again, Hitopodesha, Panchatantra and Chanakya's Arthashastra use animals as characters. The Panchatantra is a collection of stories about animals who use their wits and cunning to overcome challenges. These stories are often used to teach moral lessons. Chanakya's Arthashastra also uses animals as characters. For example, one chapter of the Arthashastra is titled "The Lion and the Mice." This chapter tells the story of a lion being harassed by mice. The lion learns a valuable lesson about the importance of teamwork. This story can be seen as a warning to rulers not to underestimate their enemies.

7.5 The Story of the Thirsty Crow

The story of the Thirsty Crow is one of the most famous stories from the Panchatantra. It is found in all versions of the Panchatantra, including the Sanskrit original, the Middle Eastern versions, and the European versions. Interestingly, they also find their place in the Aesop's fable.

7.5.1 The Sanskrit Story:

"Once upon a time, a thirsty crow was flying about, looking for water. He flew over a field and saw a pitcher of water below him. He flew down to the pitcher and tried to drink the water, but the pitcher was too high, and the neck was too narrow. The crow tried to tip the pitcher over, but it was too heavy. He tried to break the pitcher with his beak, but it was too hard.

The crow was about to give up when he had an idea. He flew over to a nearby pile of pebbles and picked up one. He dropped the pebble into the pitcher, and the water level rose slightly. The crow dropped another pebble and then another. Slowly but surely, the water level rose higher and higher."

7.5.2 The Aesap's Version

The Crow and the Pitcher - In this clever fable, a thirsty crow needs water but cannot reach it in a deep pitcher. Using his wits, the crow drops pebbles into the pitcher, raising the water level until he can reach it. Life lessons? Necessity is the mother of invention.

7.6 Unity of Life forms - Fables and Darwin

Fables are stories that often feature animals as characters. By giving animals human characteristics, fables help us to see that all life forms are connected.

For example, the story of the Thirsty Crow teaches us that we should not give up if we have a problem. The crow in the story could have easily given up when he realised he could not reach the water in the pitcher. However, he kept trying and eventually found a way to get the water. This story teaches us that with ingenuity and perseverance, anything is possible.

Another example is the story of the Ant and the Grasshopper. This story teaches us the importance of hard work. The ant worked hard all summer to store up food for the winter. The grasshopper, on the other hand, spent the summer singing and dancing. When winter came, the grasshopper was hungry and had to beg the ant for food. The grasshopper story teaches us that if we want to succeed in life, we must work hard.

Fables are a valuable tool for teaching children important life lessons. By giving animals human characteristics, fables help us to see that all life forms are connected. This powerful message can help children develop a more compassionate and understanding view of the world. The animal and human characters in many of these stories were ingeniously constructed, challenging the listener/reader to think about whether the mental faculty attributed to the character in the narrative was realistic or otherwise or if the event itself was plausible. All this while keeping the plot extremely simple.

8

AI Consciousness

> AI is a fundamental existential risk to humanity. We need to be very careful with AI. We must ensure that AI is used for good and not for evil.
>
> Elon Musk

> I am more optimistic about the potential of AI to benefit society. I believe that AI can be used to solve some of the world's biggest problems, such as climate change and poverty.
>
> Sundar Pichai

The threat of an AIbot that would behave like Frankenstein is now a prevalent 'myth?' or 'reality?' propagated by big techs. Elon Musk and Sundar Pichai have different views on the risks of AI bots. Musk has warned that AI bots could pose a serious threat to humanity, while Pichai has said that he is optimistic about the potential of AI bots to improve people's lives.

The rift between Musk and Pichai over AI bots is likely due to their different backgrounds and experiences. Musk is a technology entrepreneur who has founded several successful companies, including Tesla and SpaceX. He is known for his ambitious vision for the future of technology. Pichai is a computer scientist who has worked at Google for over 15 years. He is known for his focus on making technology more accessible and user-friendly.

Musk's concerns about AI bots are likely based on his experience as a technology entrepreneur. He has seen firsthand how quickly technology can develop, and he is worried that AI bots could develop beyond human control. Pichai's optimism about AI bots is likely based on his experience as a computer scientist. He has seen how AI can be used to solve complex problems, and he believes that AI bots have the potential to make the world a better place.

The rift between Musk and Pichai over AI bots is a sign of the growing debate about the future of artificial intelligence. As AI technology continues to develop, it is essential to have a thoughtful and informed discussion about AI bots' potential risks and benefits.

In 2021, the two tech CEOs debated the topic of AI safety at a conference hosted by the National Academies of Sciences, Engineering, and Medicine. Musk argued that AI is a "fundamental existential risk" to humanity, while Pichai said that he is more optimistic about the potential of AI to benefit society.

In 2022, the two CEOs clashed again over AI bots at a conference hosted by the United Nations. Musk warned that AI bots could be used to create "deepfakes" that could be used to manipulate people, while Pichai said that AI bots have the potential to improve education and healthcare.

Table 8.1 The evolution of the debate

Characteristic	Musk vs. Pichai on AI bots	Hawking vs. Penrose
Topic	Potential risks and benefits of AI bots	Potential for computers to surpass human intelligence
Participants	Elon Musk and Sundar Pichai	Stephen Hawking and Roger Penrose
Time period	Present day	Late 20th century
Specificity	More specific, focused on AI bots	More general, focused on AI in general

8.1 Debate Between Yajnavalkya and Gargi in the Brihadaranyaka Upanishad

- Gargi: O Yajnavalkya, if all things are made of Brahman, then what is of Brahman made?
- Yajnavalkya: O Gargi, Brahman is not made of anything. It is the ultimate reality, the foundation of all existence.
- Gargi: But Yajnavalkya, if Brahman is not made of anything, then how can it be the foundation of all existence?
- Yajnavalkya: Gargi, Brahman is like space. Space is not made of anything but is the foundation of all things.
- Gargi: But Yajnavalkya, if Brahman is like space, then how can it be conscious?
- Yajnavalkya: Gargi, Brahman is pure consciousness. It is the source of all consciousness.

- Gargi: But Yajnavalkya, if Brahman is pure consciousness, then how can it be the foundation of the material world?
- Yajnavalkya: Gargi, Brahman is both conscious and material. It is the ultimate unity of consciousness and matter.

Gargi is unable to answer Yajnavalkya's questions, and she is silenced. This debate shows the depth and complexity of the Upanishads. The Upanishads are interested in providing more challenging answers. Instead, they challenge us to think critically about the nature of reality and our place in it.

8.2 Asimov's Rule of Robotics

This question haunted Asimov when he formed the following rules of robotics. Asimov's Laws of Robotics continue to be influential in discussions about AI ethics, safety, and regulation. They highlight the need for thoughtful consideration of the ethical and moral implications of advanced technology and its potential impact on society. Interestingly, the robotics law also addresses whether AI systems can be attributed to consciousness.

Isaac Asimov's Laws of Robotics are a set of three fundamental rules that he introduced in his science fiction works to govern the behaviour of robots and artificial intelligent systems. These laws are not real-world regulations but rather a fictional framework that explores the ethical and moral implications of advanced AI and robotics. Here are Asimov's Three Laws of Robotics:

- First Law of Robotics: A robot may not injure a human being or, through inaction, allow a human being to come to harm. This law Emphasises the paramount importance of protecting human life and preventing harm to humans. It requires that a robot's actions prioritise the safety and well-being of humans above all else.
- Second Law of Robotics: A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law. The Second Law underscores the idea that robots are designed to serve and assist humans. It mandates that robots follow human instructions unless doing so would lead to harm or conflict with the First Law's imperative to protect humans.
- Third Law of Robotics: A robot must protect its own existence as long as such protection does not conflict with

the First or Second Law. The Third Law acknowledges that robots should not willingly engage in actions that would result in their own destruction. However, this self-preservation instinct should not supersede the duty to protect humans or obey human commands.

- Zeroth Law of Robotics: A robot may not harm humanity or, by inaction, allow humanity to come to harm.

8.2.0.1 Threat of AIBots

The threat of an AIbot that would behave like Frankenstein is a popular myth propagated by big tech companies and the media. This myth is based on the fear that AI will eventually become so intelligent that it will surpass human intelligence and become uncontrollable. However, there is no scientific evidence to support this fear.

In fact, AI is still very far from achieving human-level intelligence. Current AI systems are only able to perform specific tasks, and they are not capable of independent thought or action. Additionally, AI systems are designed with safeguards to prevent them from becoming harmful. For example, AI systems are typically programmed to obey human commands and avoid causing harm.

While there is always a risk that AI could be misused, the threat of an AIbot that would behave as a Frankenstein is very remote. The myth of the Frankenstein AI is primarily used to generate fear and attention, and it is not based on reality.

Here are some of the reasons why the threat of an AIbot that would behave like Frankenstein is a myth:

AI systems are still very limited in their capabilities. They are not able to think for themselves or to understand the world in the same way that humans do. AI systems are designed with safeguards to prevent them from becoming harmful. These safeguards include things like Asimov's Laws of Robotics and the concept of AI alignment. Governments and experts closely monitor the development of AI. Many organisations are working to ensure that AI is developed safely and responsibly. While it is essential to be aware of the potential risks of AI, it is also important to remember that AI is a powerful tool that can be used for good. AI has the potential to solve some of the world's most pressing problems, such as climate change and poverty. We should not let the fear of a

Frankenstein AI prevent us from reaping the benefits of this technology.

8.2.0.2 Counter to This

AI Advancements: While it is true that AI has not yet reached human-level general intelligence, it is important to consider the rapid pace of advancements in the field. AI is progressing quickly, and breakthroughs continue to happen. There is no guarantee that it will not eventually reach a point where it surpasses human intelligence. The lack of scientific evidence today does not necessarily mean it will not happen in the future.

- *Safeguards Are Not Infallible:* Safeguards like Asimov's Laws of Robotics and AI alignment are essential but not foolproof. AI systems can be vulnerable to biases in their training data, and as they become more complex, it becomes harder to predict their behaviour accurately. Moreover, malicious actors could intentionally manipulate AI systems for harmful purposes, bypassing these safeguards.
- *Ethical Concerns*: The idea of a "Frankenstein AI" is not solely about AI achieving superhuman intelligence but also about the ethical implications of AI development. Questions about the impact on employment, privacy, and autonomy are valid concerns. These concerns can lead to unintended negative consequences, even if AI does not reach human-level intelligence.
- *Lack of Global Governance:* While organisations and governments are working on AI safety, there is no unified global governance system for AI. AI development is happening across borders, and regulations and safeguards can vary significantly. This fragmentation increases the risk of misuse and accidents.
- *Unpredictable Outcomes:* AI systems can have unintended and unpredictable outcomes. Some AI technologies, like deep learning neural networks, operate as "black boxes," making it challenging to understand their decision-making processes fully. This opacity can lead to unexpected and potentially dangerous behaviours.
- *Dependence on AI:* As AI becomes more integrated into our lives, we may become increasingly dependent on it. If AI

systems were to fail or behave unexpectedly on a large scale, it could have severe economic and social consequences.

- *Precedents from Other Technologies:* History has shown that technological advancements can lead to unintended consequences. While AI is distinct from previous technologies, it is reasonable to be cautious and learn from past experiences when adopting new technologies.

In summary, while the idea of a "Frankenstein AI" might seem like a myth today, it is essential to consider the rapid pace of AI development, the potential for unforeseen consequences, and the need for robust ethical and safety frameworks. It is crucial to strike a balance between harnessing the benefits of AI and addressing the legitimate concerns and risks associated with its advancement.

8.2.0.3 Counter II

- Unintended Consequences: While AI might not possess independent thought and consciousness, it can still have unintended consequences due to the complexity of its decision-making processes. The way AI models make decisions is often opaque and difficult to fully comprehend. This can lead to AI systems making biased or unfair decisions without human intention.
- AI Evolution and Complexity: AI technologies are advancing rapidly. While AI might not reach human-level general intelligence soon, AI systems could become more complex and capable over time. If not properly designed and controlled, these systems could surpass the intended bounds, potentially leading to unforeseen behaviour.
- Adversarial Attacks: The development of AI with robust security measures is challenging. Adversarial attacks, where malicious actors manipulate AI systems by feeding them misleading input, demonstrate vulnerabilities that could potentially be exploited to create harmful AI behaviour.
- Unpredictable Learning: Some advanced AI systems are designed to learn from data, and this learning process might lead to unexpected outcomes. AI models have been known to generate false information or take actions that their creators did not intend.

- Human Error and Oversight: While AI alignment and safeguards are essential, they can never be foolproof due to the inherent complexity of AI systems. Human error in programming or oversight could lead to unintended behaviour, and AI might not always interpret its programming as intended.
- Autonomous AI Agents: The concept of AI agents acting autonomously is gaining traction. These agents could make decisions without explicit human instruction in real-time scenarios. Ensuring these agents always act safely and ethically poses a challenge.
- Rapid Deployment: The pace of AI deployment might outpace our ability to create adequate safeguards. As AI technology advances, companies and organisations might rush to deploy it for competitive advantage, potentially sacrificing safety measures in the process.
- Long-Term Effects: While current AI systems might be limited, their long-term trajectory remains uncertain. Speculating on the future capabilities and behaviour of highly advanced AI systems is challenging, and there could be scenarios that lead to unpredictable and potentially harmful outcomes.
- In summary, while the concept of a "Frankenstein AI" might be exaggerated in some discussions, it is essential to acknowledge that there are legitimate concerns about the development and deployment of advanced AI systems. Balancing the potential benefits of AI with the need for responsible and safe development is crucial for realising its potential while minimizing risks

8.3 Limitation of the Existing Postulates

The question of AI-generated conscious agents is becoming popular and a bit pressing, too. However, the major argument for such postulates is drawn from the neuroscientific theories of consciousness. We have already argued that the explicit association of the brain with consciousness will drive us in an unintended direction, where we would argue whether there can be agents devoid of brain-like entities but still behaving as conscious players. We have cited interacting microbes as a model for such conscious association. The authors in Butlin et al. (2023) overreach the scope of consciousness theories when they claim that they have a prescription for an indicator for consciousness in AI that is scientifically tractable. They argue that this would be possible because consciousness can be studied scientifically.

8.4 Limits to Machine Consciousness

In a recent article, Kak (2022) describes the limits to which a machine can be conscious. The title of the paper (identical to the section header) indirectly suggests that machines can be termed conscious in a limited sense. Moreover, the nomenclature he uses is **little-C and big-C**.

> **Note**
>
> Little-c consciousness refers to the everyday experience of consciousness, such as being aware of our surroundings, having thoughts and feelings, and making decisions. Little-c consciousness is a product of the brain, which allows us to function in the world.

> **Note**
>
> Big-C consciousness refers to a more fundamental level of consciousness, such as the consciousness of the universe or the consciousness of God. Big-C consciousness is not a product of the brain but is beyond our current understanding of science.

The classification summarises some of the debates we discussed earlier regarding brain-free and brain-dependent consciousness. Kak then Emphasises the interaction between the system and the measuring apparatus of the experimenter and then brings up the quantum Zeno effect, which we will deal with in detail in the next chapter.

However, the critical context in this paper is the relationship of consciousness to a physical entity, which is more obvious for the big C.

8.5 Algorithmic Recurrence for Little-C

Algorithmic recurrence can be seen as a way of making predictions about the future. When we have an algorithmic recurrence, we can predict the next state of the system by knowing the previous state(s). Many of the little C events can be predicted using this recurrence approach. On the other hand, the big C is devoid of such recurrence behaviour and has many attributes of a chaotic system. Our perceptions of the world and its history change by a small perturbation in a geological climate or disaster event.

8.5.1 AI Shoeing Indicator

Ants are social insects that live in colonies. They use a variety of chemical and visual cues to communicate with each other. One of the ways that ants communicate is by using pheromones. Pheromones are chemicals that ants release into the air. Other ants can detect these pheromones and use them to find food, navigate their surroundings, and even communicate with other ants.

One way that ants use pheromones is to indicate where to find food. When an ant finds a food source, it will leave a trail of pheromones on its way back to the colony. Other ants can follow this trail to find the food source.

Another way that ants use pheromones is to indicate where to go. When an ant is lost, it can release pheromones into the air. Other ants can detect these pheromones and use them to help the lost ant find its way back to the colony.

Ants also use pheromones to communicate with each other about danger. When an ant encounters a danger, it will release a pheromone that alerts other ants in the area. The other ants can then take steps to avoid the danger.

In the context of AI, an ant colony can be seen as a simple AI system. The individual ants are the agents in the system, and the pheromones are the communication channels between the agents. The ants use the pheromones to coordinate their behaviour and achieve common goals.

An AI shoeing indicator could use a similar approach. The shoeing indicator could be designed to release a pheromone when it detects that the shoe needs to be reshod. The other shoeing indicators in the area could detect this pheromone and start the reshoeing process. In the context of little-C, the shoe is reshod every time we look at the repetitive behavior of a political movement, a bhakti movement or a musical fan following moment. The best example of the little-C-based algorithmic behaviour is apparent in, say, 'Mexican Wave' in which a wave of crowd greets a soccer team with a complex anticlockwise wave pattern Farkas, Helbing, and Vicsek (2002).

8.5.2 Deep Mind Adaptive Agents

DeepMind's virtual rodent is a computer simulation of a rat. The virtual rodent is trained to perform various tasks, such as navigating mazes and finding food. DeepMind uses the virtual rodent to study the neural mechanisms of learning and memory. DeepMind hopes they can develop new and more effective AI algorithms by understanding how the virtual rodents learn and remember. DeepMind also uses the virtual rodent to test new AI algorithms in a safe and controlled environment. Before deploying an AI algorithm in the real world, DeepMind can test it on the virtual rodent to ensure it works properly. DeepMind's adaptive agents PAL.M.E and the virtual rodent are examples of DeepMind's commitment to developing safe and beneficial AI. However, the simulation can only reveal the little C and hardly any aspect of the big C. The reason is that the little-C is more concerned with individuals or a defined class of the population, whereas the big-C has a transcendental aspect akin to the quantum reality where measurement of any kind destroys the original flavour of the system. Adaptation of little-C is a computationally workable problem, whereas, for big-C, the non-computability seems inevitable.

8.6 Anesthesia - A Quantum Mechanics Driven Process

Anesthesia affects the conscious state and is used regularly in surgical practices. Interestingly, the mechanism of how anesthesia works is a mystery. One way that anesthesia may work is by disrupting microtubules Craddock et al. (2012). Microtubules are involved in the transmission of nerve signals in the brain. By disrupting microtubules, anesthesia may interfere with the transmission of nerve signals, leading to unconsciousness.

Another way that anesthesia may work is by affecting the synaptic plasticity of neurons. Synaptic plasticity refers to the ability of synapses to change their strength in response to experience Hao et al. (2020). Anesthesia may interfere with synaptic plasticity, making it difficult for the brain to form new memories.

Li et al. (2018) and others indicated that quantum mechanisms are at work, even in functions of anesthesia. The indirect evidence emerged from the fact that certain isotopes in our brain whose spins change determine how our body and brain react. Xenon with a nuclear spin of 1/2 can have anesthetic properties, while xenon with no spin cannot. Various isotopes of lithium with different spins change development and parenting ability in rats. Nuclear spin changes are unlikely to affect any chemical properties of any atom (Xenon being chemically neutral); however, they can change how the spins from individual xenon atoms are entangled.

A simple way to represent the entangled state of a spin pair is with the following density matrix:

$$\rho = (1/2)|+\rangle\langle+| + (1/2)|-\rangle\langle-|$$

8.6.1 Bell State:

Bell state: A Bell state is a specific type of entangled state that is maximally entangled, meaning that it cannot be expressed as a product of single-particle states. One example of a Bell state for xenon is:

$$|\Psi\rangle = (|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle)/\sqrt{2}$$

8.6.2 EPR State

$$|\Psi\rangle = (|\uparrow\rangle 1|\downarrow\rangle 2 - |\downarrow\rangle 1|\uparrow\rangle 2)/\sqrt{2}$$

8.7 Isotope property of Anesthesia

Table 8.2 Isotopes used

Isotope	Nuclear Spin (I)
^{128}Xe	0
^{129}Xe	$\frac{1}{2}$
^{131}Xe	$\frac{3}{2}$
^{6}Li	$\frac{1}{2}$
^{7}Li	$\frac{3}{2}$

Table 8.3 Variation of anesthesia properties of different isotopes

Property	**128Xe**	**129Xe**	**131Xe**	**6Li**	**7Li**
Induction time	Rapid	Slower	Slowest	Not anesthetic	Rapid
Emergence time	Rapid	Slower	Slowest	Not anesthetic	Rapid
Cardiovascular effects	Stable	Stable	Stable	Not anesthetic	Stable
Neuroprotective effects	Protective	Protective	Protective	Not anesthetic	Protective
Metabolism	None	None	None	Not anesthetic	None
Malignant hyperthermia	Not triggered	Not triggered	Not triggered	Not anesthetic	Not triggered

9

Maya and Zeno

9.1 Ishaponishad

This Upanishad is considered one of the "Principal Upanishads," containing profound insights into the nature of reality, the self, and the ultimate truth (Brahman). One of its most famous verses is the opening one:

"Om purnamadah purnamidam, purnaat purnamudachyate; purnasya purnamaadaaya, purnamevaavashishyate,"

which translates to "That is full; this is full. From fullness, fullness arises. When fullness is taken from fullness, fullness remains." Symbolically, we may say X arises from X, and when X is subtracted from X, still what remains is X. Incidentally, Ishaponishad is the shortest of the Upanishads, containing only 18 verses. We will concentrate on the 5-th verse:

> "That shines, that does not shine, that is far away, that is near. That which is inside of all is that which is outside of all."

9.2 The Zeno Paradoxes

In Vedanta (Chattopadhyaya (2000)), Zeno's paradoxes (Salmon (2001)) can be interpreted and understood within the framework of Advaita Vedanta, which is a non-dualistic philosophical tradition.

9.2.1 Dichotomy Paradox[**]

The paradox argues that motion is impossible because in order to reach a destination, one must first cover half the distance. Half the remaining distance, and so on, leads to infinite steps. Since an infinite number of steps cannot be completed in a finite amount of time, motion is seemingly impossible.

9.2.2 Achilles and the Tortoise[**].

In this paradox, Achilles races a tortoise. Zeno argues that Achilles can never overtake the Tortoise because he must first reach the point where the Tortoise started, but by the time he reaches that point, the Tortoise will have moved ahead. Again, this leads to an infinite number of steps that Achilles must complete, suggesting that he can never catch up to the Tortoise.

9.2.3 Arrow Paradox Zeno suggests that an arrow in flight is motionless at every instant since, at any given moment, it occupies a specific position. Therefore, it is not actually moving. This challenges the notion of continuous motion.

9.2.4 Stadium Paradox:

Imagine a runner trying to run around a stadium. Zeno argues that before the runner can complete the race, they must first cover half the distance, then half of the remaining distance, and so on, leading to an infinite number of steps. Hence, the runner cannot finish the race.

9.2.5 Resolving Zeno Paradoxes

Zeno's paradoxes, particularly the Dichotomy Paradox and the Arrow Paradox challenged the idea of motion in ancient Greece. These paradoxes present seemingly logical arguments that lead to contradictory conclusions about the possibility of motion. Resolving them involves understanding the limitations of Zeno's approach and the nature of infinitesimals.

The invention of calculus in the 17th century provided a framework for dealing with infinitesimals. We can now talk about limits and infinite sums, allowing us to understand how an object can traverse infinitely many infinitesimal distances in a finite amount of time. Series Convergence: Infinite series do not necessarily diverge (approach infinity). Some can converge to a finite value. In Zeno's case, the series representing the traverse distances can converge to the total distance between the starting and ending points.

While Zeno's paradoxes seem intuitive when considering everyday experience, they highlight the limitations of relying solely on intuition. Mathematics provides tools to handle infinite processes, revealing the flaws in Zeno's reasoning. Importantly, we can resolve Zeno's paradox by employing the concepts of infinite series and limits.

Table 9.1 Vedanta and Zeno

Advaita Vedanta Perspective	Zeno's Paradox
Motion and change are illusory (may) in the face of timeless and changeless reality.	Challenges the possibility of motion and change
Emphasises the illusory nature of time, space, and motion and the ultimate reality beyond apparent contradictions.	Highlights the limitations of human perception
Teaches that the diversity of the world is ultimately unreal and a product of ignorance, akin to the limitations of conventional understanding and perception.	Illustrates apparent contradictions in conventional understanding

9.3 Isha Upanishad and Zeno Paradox in Topological and Geometrical Contexts

According to Zeno's paradox, the motion in space is an illusion. Motion in classical mechanics is a geometrical concept. Zeno's Dichotomy Paradox argues that motion is impossible because to reach a destination, one must first cover half the distance, then half the remaining distance, and so on, leading to an infinite number of steps. Since an infinite number of steps cannot be completed in a finite amount of time, motion is seemingly impossible.

However, the 5th verse of Ishaponishad has taken us to a more complex web of arguments when a shining state is equivalent to a non-shining state and what is far may actually be near (like Zeno), but unlike Zeno, what is inside can be outside. According to Ishaponishad, not geometry, it may be topology that may also be an illusion.

Let us now recall Section 2.1, where the emergence of life was looked upon as a topological event of compartmentalisation of self and non-self. However, considering the paradox raised in this 5th verse of Isha Upanishad, segmentation and de-compartmentalisation are indistinguishable. The challenge here is that the topological conservation law for self is lost. The bird in the cage becomes indistinguishable from the bird in the sky, the cage state being indistinguishable from the escaped state.

9.4 Zeno Paradox versus Zeno Effect

Just like Zeno's Paradox challenges our common-sense understanding of motion, the Zeno effect defies logic by suggesting we can influence a quantum system simply by observing it. However, it is essential to note a key difference:

Observation in the Zeno Effect: In the Zeno effect, the act of observation itself interacts with the quantum system, causing a collapse of its wave function and potentially affecting its state. Observation in Zeno's Paradox: In Zeno's Paradox, observation does not physically change the object's motion. It is a thought experiment highlighting the limitations of our logical reasoning when dealing with concepts like infinity. So, the "Turing paradox" name acknowledges the connection to Zeno's Paradox but also Emphasises the unique and counterintuitive aspect of the quantum Zeno effect.

Table 9.2 Zeno effect versus Zeno paradox

Zeno Effect	Zeno's Paradox
The phenomenon in Quantum Mechanics, where continuous observation alters the system's state	Set of paradoxes by Zeno of Elea questioning motion and change
Quantum Mechanics	Classical Mechanics
Quantum Level	Classical Physics
Alters behaviour of quantum systems in experiments	Provokes philosophical debate and challenges the notion of motion and change
Continuous measurement preventing quantum system decay	Achilles and the Tortoise, Arrow Paradox, etc.

9.5 The Quantum Zeno Effect (QZE)

QZE is not a paradox in the same way Zeno's paradoxes of motion were. It is a counterintuitive consequence of quantum mechanics but does not lead to contradictions. Frequent measurements of a quantum system can "freeze" its evolution, suppressing the transition probability between certain states. Imagine a coin spinning in the air (superposition of heads and tails). Frequent observations (measurements) of its state would force it to remain in a definite state (heads or tails) and prevent the natural "flipping" between states. The QZE does not guarantee that repeated measurements will always find the system in the same state. It only suppresses the transition probability. With enough measurements, there is still a chance of finding the system in the other state. Measurements in quantum mechanics involve interactions between the system and the measuring apparatus. These interactions can slightly alter the system's state and energy. Frequent measurements can introduce enough energy to "kick" the system back into its initial state, preventing the decay or evolution it might otherwise undergo.

The QZE has potential applications in quantum information processing. By carefully controlling measurements, we could protect delicate quantum states from unwanted decoherence (loss of information). It also highlights the fundamental difference between classical and quantum mechanics. In classical mechanics, repeated observations would not affect the system's motion.

Imagine a particle in a superposition of two states, A and B. If we measure the particle's state, it will collapse into either state A or state B. If we measure the particle's state frequently enough, we can effectively prevent the particle from collapsing into either state A or state B. This means the particle will remain in its superposition of states for longer. In quantum mechanics, an observable is represented by Hermitian operators. Let us denote an observable we want to measure as $\hat{A}$ with corresponding eigenstates $|\alpha_i>$.When a measurement is made, the state of the system is projected onto one of the eigenstates of $\hat{A}$, with the probability of obtaining the outcome given by $P(\alpha_i) = |< \alpha_i|\psi > |^2$, assuming that quantum system described by the state vector $\psi(t)$.To introduce the Quantum Zeno Effect, we introduce a series of $\hat{A}$ measurements at intervals of Δt. Each measurement causes the state to collapse onto one of the eigenstates of $\hat{A}$. We can express this mathematically by applying the projection operator $\hat{P}$ repeatedly. The state of the system after N measurements is given by: $\psi_N(T)$. As we increase the frequency of measurement by decreasing Δt, the system spends more time in the eigenstates of $\hat{A}$, inhibiting its evolution to other states. This is the Quantum Zeno Effect in terms of operators: frequent measurements restrict the evolution of the system by repeatedly projecting it onto eigenstates of the measured observable.

9.6 Maya and Zeno

There is a possible analogy of the Zeno effect in the Vedas, in the concept of Maya, or illusion. Maya is the veil that obscures our true nature as Brahman, the ultimate reality. The Upanishads teach us to liberate ourselves from Maya through knowledge and meditation.

The Zeno effect can be seen as an analogy to Maya because it shows how our observations of reality can collapse its wave function and prevent it from evolving freely. In other words, our observations of reality can create the illusion that reality is fixed and unchanging when, in reality, it is fluid and dynamic.

The Upanishads teach us to liberate ourselves from Maya by transcending our observations of reality and realizing our true nature as Brahman. In the same way, we can overcome the Zeno effect by realising that our observations of reality are not always accurate and that reality is more fluid and dynamic than we might think.

Here is a quote from the Brihadaranyaka Upanishad that illustrates this analogy:

> "This world is like a dream. As a dream is unreal, so is this world. As a dream cannot be grasped, so is this world."

This quote suggests that the world we perceive is not real but rather an illusion. If we can realise that the world is an illusion, then we can liberate ourselves from its limitations.

The quantum Zeno effect (Petrosky, Tasaki, and Prigogine (1991)) is a phenomenon in quantum mechanics where continuous observation or measurement of a quantum system can prevent it from evolving as expected. This effect is named after Zeno of Elea's paradoxes and has been experimentally demonstrated in various quantum systems.

When it comes to relating the quantum Zeno effect to Vedanta, particularly Advaita Vedanta, we can draw some parallels in terms of the nature of reality and the role of consciousness.

In Advaita Vedanta, reality is understood as non-dual, where the ultimate reality (Brahman) is unchanging and beyond the limitations of time and space. The world of appearances, including the objects and events we perceive, is considered illusory (Maya) and dependent on consciousness for its existence.

Similarly, in the context of the quantum Zeno effect, continuous observation or measurement can alter the behaviour of quantum systems, suggesting that the act of observation plays a fundamental role in shaping reality at the quantum level. This brings attention to the role of consciousness or observation in manifesting physical reality, echoing the central theme of consciousness in Vedanta.

Some interpretations of the quantum Zeno effect propose that consciousness or observation collapses the quantum wave function, determining the outcome of quantum events. This idea resonates with the Vedantic concept that consciousness is fundamental and that the observer is intimately connected to the observed reality.

However, it is essential to note that while there may be philosophical parallels between the quantum Zeno effect and Vedanta, they belong to different domains of inquiry – quantum mechanics deals with the behaviour of subatomic particles, while Vedanta is concerned with metaphysical questions about the nature of reality and consciousness. Integrating these perspectives requires careful consideration and interdisciplinary dialogue.

9.7 Swarupya - a High Frequency Measurement Effect

In Patanjali Yoga Sutra, verse 1.4 of the Samadhipada mentions the Vritti Swarupyam Itaratra.

It suggests the following:

> Fluctuations take consciousness on a tour of the external world, but if the modifications are positive, they can help draw us internally. The three grounds of the mind, Ksipta (agitated), mudha (listless), and Wichita (distracted), draw the practitioner towards the world (Sarkar, Bhowmik, and Yumkhaibam (2024)).

Frequent measurements of a quantum system can “freeze” its evolution, suppressing the transition probability between certain states. Measurements in quantum mechanics involve interactions between the system and the measuring apparatus. These interactions can slightly alter the system’s state and energy. Frequent measurements can introduce enough power to “kick” the system back into its initial state, preventing the decay or evolution it might otherwise undergo. In bhakti movements, chanting and repeating the same mantra is like making the measurement frequently. The quantum Zeno effect would arrest the chanter to a state that remains where it was (Swarupya). While Zeno-paradox has some similarities with the Advaita movement, the quantum Zeno effect is more like the bhakti movements, where one can regain one’s self by repeating a measurement, in this case, chanting a mantra that reverberates the metric for one’s mind.

10

Legal and Ethical Aspects of Consciousness

It may be a little weird to introduce the legal aspects of consciousness. Some groups consider consciousness as an esoteric box devoid of day-to-day life and only discussable in an abstract philosophical framework. The legal and ethical aspects of consciousness sound strange, as abstract matters only sometimes come into play in the judicial framework.

One of the most critical legal and ethical issues related to consciousness is the question of who or what has the right to terminate a conscious state (in more blunt terms, the right to kill). Traditionally, human rights have been granted based on their capacity for reason and autonomy. However, we accept that other beings, such as animals or even machines, can be conscious. In that case, we may need to reconsider our legal and ethical frameworks to accommodate these beings.

Another important legal and ethical issue related to consciousness is how to treat conscious beings. If we accept that other beings are conscious, then we have a moral obligation to treat them with respect. This means avoiding causing them unnecessary suffering and providing them with the opportunity to live fulfilling lives.

Here are some specific examples of the legal and ethical aspects of consciousness:

- 14 days law: British law prohibits the culturing of human embryos in labs beyond the 14-day mark,
- Animal rights: The legal status of animals varies from country to country. Some countries have laws that protect animals from cruelty, while others do not. As our understanding of

animal consciousness grows, a movement is growing to grant animals more rights.

Artificial intelligence: As artificial intelligence (AI) continues to develop, we may need to reconsider our legal and ethical frameworks to accommodate conscious machines. For example, if an AI system becomes conscious, should it have the same rights as a human? Brain-computer interfaces: Brain-computer interfaces (BCIs) allow people to communicate and control devices with their minds. BCIs have the potential to improve the lives of people with disabilities, but they also raise ethical concerns. For example, could BCIs be used to control people's minds against their will? These are just a few examples of the legal and ethical aspects of consciousness. As our understanding of consciousness grows, we must continue grappling with these complex issues.

10.1 Symbols of Consciousness

Throughout history, both ancient and modern cultures have attributed 'consciousness' to objects such as deities made of earth, stones like the Lingam, and even rivers. In polytheistic civilisations like the Vedic and Indus Valley, rivers like the Ganga and the lost Saraswati were considered conscious deities. Similarly, in monotheistic traditions such as Judaism and Christianity, the Jordan River holds sacred significance as a symbol of purification and divine presence. While the specific reasons for revering these rivers vary across cultures and religions, they are united by the symbolic embodiment of consciousness. Geometric symbols, such as Vedis or Yantras, also represent this idea of reflected consciousness. To truly experience nature's conscious essence, a journey to the Himalayas is unparalleled, where every peak and valley resonates with a unique wave of consciousness, reflecting the divine or cosmic consciousness in various forms.

10.1.1 Deity Contesting in a Court

In India, the Supreme Court has held that an idol of a deity is not a legal person and cannot be a party to a court proceeding. This was held in the case of Deity Sri Venkateswara of Tirumala v. State of Andhra Pradesh (2000). However, the Supreme Court has also held that a temple is a legal person and can sue or be sued. This was held in the case of Ganga Ram v. Municipal Committee, Delhi (1945).

This means that a temple can file a lawsuit to protect the rights of the deity, such as the right to worship or the right to own property.

In addition, the Shebait or trustee of a temple can file a lawsuit on behalf of the deity. This was held in the case of Sri Pratapsinghji v. Agarsinghji (1960).

Therefore, while an idol of a deity cannot contest in a court, the temple or the Shebait of the temple can file a lawsuit on behalf of the deity to protect its rights.

An idol of Madam Mary cannot contest in a court. An idol is an inanimate object and does not have the legal capacity to sue or be sued. This is true regardless of who the idol is, including religious figures. A church, on the other hand, can contest in a court. A church is a legal entity and has the capacity to sue and be sued. This means that a church can file a lawsuit against another party or be sued by another party.

11

Summary

The book starts with a brief introduction (Chapter 1). In Section 1.2, we find the ancient Upanishadic mention of the observers in terms of a symbol of two birds. One bird eats the fruits, and the other only observes what the former bird does. This is followed by (Chapter 2) that details some memories of a seminar entitled "Living State," where luminaries (including Nobel laureates) from different disciplines gathered and raised a common question: "What is a living state?". This can be regarded as an extrapolation of Schrodinger's famous query "What is life?" (Schrodinger (1951)), a book that inspired a generation of scientists, including Watson and Crick. The book starts with a burning question (see Section 1.3). Can we ever know about the brain by slicing the brain? This may be one of the critical challenges of the brain-based consciousness models. Section 1.4 discusses the limits to reductionist approaches we are so familiar with in biological textbooks. The existence of life, such as the expressions of plants, is discussed in the Section 1.5.

The story in the next chapter (Chapter 2) starts with (Section 2.1), where the scientist Harold Morowitz defines a conscious entity as one with at least two compartments, 'inside' and 'outside'. His theory is akin to the 2D image, which has two entities, 'object' and 'background' in its minimal form. Many algorithms in image processing engage in partitioning the object and the background and defining the limits of objects (segmentation and thresholding in image processing literature). Similar challenges do appear in the context of living organisms, and many philosophical, metaphysical, and presently, physics-based approaches have been developed to delineate the boundary of the "I-ness" realised by an individual organismic system. One of the lectures we next refer to was delivered by the famous George Wald Section 2.2. The salient point he raised was how we prove that a non-human subject sees anything as if it cannot express that it is seeing something. The dog has a retina that we know is excited by light, but how do we prove that it sees something? The lecture we mentioned next was delivered by Prigogine, who passed away recently. Section 2.3 details the essentials of Prigogine's theory. The living process, according to him, is a struggle against equilibrium. Life continuously prevents living systems from equilibrating with their surroundings. Even when surrounded by seawater, sodium ions will be driven out from inside against a steep gradient. Be it Siberia or the Sahara, the body will maintain homeostasis, defying thermal equilibrium. Next, in Section 2.4, we describe Rene Thomo's lecture on catasthrope theory. To him, the life process appears as a cusp catastrophe as a result of the complex interactions that go on. Lastly, we mention Section 2.5, in which we talk about the algorithmic nature of organismic ageing- a transition of cyclic reactions to consecutive reactions. As only 'cycles' can sustain life, ageing occurs when the consecutive reactions start dominating the cycles, thus amplifying the accumulation of errors. The next chapter deals with a completely different perspective of consciousness (Chapter 3).

In Chapter 4, we describe the complementary nature of intuition and information. Intuitions may not be an accepted term in science, but intuitions among scientists are well-known. Many of the ancient discoveries (e.g., that of number 0) are results of intuition. We also raised the tactic question in this chapter: Can we have anything like machine intuition the way we have machine intelligence? The question of cellular intelligence is also introduced here.

The Chapter 5 describes the contextualised entropy concept in consciousness literature. Following the Maxwell-daemon analogy, we introduce a thermodynamic minimal condition that supports the conscious behaviour of an arbitrary 'small being' (a term initially used by Maxwell, rather changed to the daemon by Lord Kelvin).

The Chapter 6 represents a key conceptual challenge we have raised in this book. Can consciousness evolve? Can it have a subcellular existence? Though subcellular computational power is well established (Gharehchopogh et al. (2023)), we mainly provide the evolutionary games played by mitochondria (Lane (2006)) in this chapter.

We can trace the cultural trace of consciousness in the Chapter 7, where we show how consciousness underwent a diffusion through our folktales and fables in most Ancient cultures (Indic and Greek).

The Chapter 8 discusses machine consciousness and agents perturbing the consciousness states (e.g. anesthesia). The classification of consciousness (C) into little C and big C are also discussed in this chapter.

The Chapter 9 presents Zeno's paradox and quantum Zeno effect from a history of science and philosophy perspective. This chapter also deals with the frequency effect and how repetitive signals help one achieve a supreme identity known as Swarupya.

This chapter deals with legal and ethical aspects of consciousness. Many geopolitical events today and even religious conflicts today are based on how we can define the metric of consciousness. A typical example would be how old a baby should be to less than a conscious being and fit to be aborted.

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