JUAN PEDRO RODRÍGUEZ

SUPERCOMPLEX KNOWLEDGE

The New Emerging Paradigm for Exploring the Complexity of the Universe, Life, and the Human Brain

Comunidad del Saber Supercomplejo

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Supercomplex Knowledge (SK) is the groundbreaking paradigm that unifies and transcends classical approaches to complexity, integrating scientific and philosophical theory, technology, and practical application to transform systems at every level. From advanced four-dimensional software modeling to international training and consultancy, SK drives innovation and development in a world where complexity is the norm.

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PROLOGUE

A central question in philosophy and science is: How do the universe and life evolve, and what does this reveal about the meaning and destiny of human existence? This question has permeated the entire history of human thought, and its answers have given rise to various anthropological models and social cons-tructs. However, in the 21st century, the issue takes on a new dimension. Why do we choose the path of complexity to approach it?

Many thinkers agree that the 21st century is, undeniably, the "century of complexity." Advances such as Artificial Intelligence, Data Science, Deep Learning, and Neurosciences have revolutionized our ability to model and understand all the interconnected dynamic structures of the universe, life, and the brain, among others. In another domain of contributions to consider, technoengineering has played a crucial role in the development of advanced instruments such as sensors and specialized software, significantly expanding our ability to observe and analyze complex systems in their quantum, physicochemical, and biological dimensions. These tools have enabled scientists to obtain more precise, real-time data, facilitating a better understanding of complex phenomena and helping to formulate new questions and theories across various fields of study.

Supercomplex Knowledge (SK) identifies three central components, energetic, spatial, and temporal, as the fundamental building blocks of any complex system. Energy, in all its forms (including conceptual and analogical), acts as the driving force of interactions and changes. Space provides the physical and structural context where these interactions occur, while time determines the rhythm and sequence of processes of change and evolution. These three elements, in their interaction, offer a comprehensive framework for explaining the dynamics of complex systems, encompassing essential dimensions of both physics and biology.

We ask ourselves: If reality is interaction, what does it truly mean to understand it? How do complex systems emerge and evolve, and what strategies allow us to intervene in them? And in a world of interconnected systems, how is knowledge constructed?

To begin with, it is important to recognize that the interaction between energy, space, and time produces both persistent and emergent phenomena such as self-organization, adaptation, evolution, and other behaviors analyzed in detail in this work. These behaviors, derived from fundamental interactions, are crucial to fully understanding the complexity of a system, its identity and transformation. Ultimately, the richness of complex systems lies in how these basic components combine to give rise to both predictable and unexpected, sophisticated behaviors.

Beyond the primary role of energy, space plays a fundamental role: structural morphologies allow complex systems to expand or contract, adapting to the energetic and temporal forces that traverse them. This paradigm highlights how systems not only respond to contact and interaction dynamics but also shape their internal structure to generate new dynamics and behaviors.

For SK, complexity results from a delicate balance between two opposing but complementary impulses: the impulse to remain and the impulse to change. This circular tension defines not only the behavior but also the evolution of complex systems, from subatomic particles to ecosystems and human societies. On one hand, the dimension of permanence is marked by resistance, conservation, and resilience. Systems seek to preserve their identity, optimize their resources, and maintain their structural cohesion, even in challenging environments. On the other hand, the dimension of change manifests in processes of emergence and transformation: unexpected fluctuations, asymmetries, interactions, and reorganizations that generate new possibilities.

This dynamic is key to understanding why the universe cannot be entirely ordered or entirely chaotic. A rigidly ordered universe would lack the flexibility necessary to evolve and adapt, while a chaotic universe would be unable to sustain structures, interactions, or stable systems. Only in the delicate balance produced by probabilities do life, complexity, and the creativity of the cosmos emerge.

In this book, we will explore how this tension between permanence and change offers a new way to understand complex systems. Throughout its chapters, we will analyze how energy, space, and time flow through the universe and how the forces of conservation and transformation interact to shape the reality we inhabit.

"Supercomplexity", one of our central concepts, adds modalities to complexity and is defined as a dynamic and multi-dimensional process that incorporates the effects of overlap between the macrosystems (microparticles, macroscopic, and biological), along with the active modification and cognitive and technological reconfiguration by the human observer-developer. By introducing the bidirectional and evolutionary interaction between the human brain, macrosystems, and advanced technological tools, an expansive paradigm is created that opens new possibilities for describing, predicting, and transforming systems. SK is proposed as a dynamic, integrative, and adaptive theory capable of actively intervening in the systems it studies.

Beyond merely observing complexity, it builds a coherent framework for action that evolves without losing depth, offering a supercomplex vision of the universe, life, and the human brain, with significant points of contact with network theory, cybernetics, and nonlinear dynamics.

The objective of this work is to present a unifying and surpassing proposal in response to the current mosaic of frameworks that constitute the Theories of Complexity. In its present state, this field is characterized by a diversity of approaches that are often disconnected, difficult to access, and with limited application in the hard sciences and social and human issues. SK incorporates and expands on the contributions of Complex Thought, Complexity Sciences, and other relevant theoretical frameworks to strengthen and invigorate more integrative and advanced perspectives.

The main axes of our proposal include:

A. A redefinition of the object of study that surpasses the extreme positions of seeing a "broad" "inherent complexity of the universe" or a "narrow" "collection of emergent novelties."

B. A reconstruction of the central elements that drive the dynamics of change in the universe and life (complex systems with energy flows, structural morphologies, and temporal connectivity in interaction).

C. An epistemological and gnoseological positioning from "multi-scalar complex constructivism."

D. A reinterpretation of energy, space, and time in terms of complexity.

E. The development of the novel concept of "super-complexity", understood as the result of the effects of overlap between macrosystems alongside the active modification and cognitive and technological reconfiguration by the human observer-developer.

F. A proposed taxonomy of macrosystems (microparticles, macroscopic, and biological), derived complex systems, and subsystems.

G. A model of dynamic triple overlap among the three macrosystems.

H. A description methodology that integrates mathematical, computational, and conceptual approaches.

I. The inclusion of intangible complex behaviors arising from the self-conscious system, the socio-relational system, and the symbolic system in dynamic interaction.

J. The construction of maps and algorithms and their corresponding linkage as tools to discover, understand, predict, and manipulate the dynamics and structures of complex systems.

K. The incorporation of concepts and methodologies from AI, data science, neurosciences, and new approaches within Complexity Theories.

L. The presentation of a program for institutional and corporate transformation and enhancement, culminating in sequences of algorithms to account for the progress and potential improvement of concrete complex systems, with applicability to major social and planetary issues.

M. A revision of current anthropological categories, postulating the emergence of the "Homo Supercomplexus" in this new era of the Technocene.

SK provides, as a secondary effect, a promising alternative to integrate classical, relativistic, and quantum physics while proposing a model that connects these disciplines with the biological and social sciences. With 4D multilayer graphical tools and advanced simulations, SK sets new standards for analyzing and intervening in complex systems.

The possibility that SK's mathematical formulas may be applicable to microparticle, biological, and macroscopic systems alike grants it theoretical versatility attractive to scientists and technoengineers across various fields. Moreover, the simulation and visualization of complex networks in 4D open the door to practical applications in multiple industries. As we will demonstrate, SK has the potential to revolutionize fields where the prediction and modification of complex systems are fundamental.

The idea that there is no single arrow of complexity but rather a bidirectional overlap between macrosystems, microparticles, macroscopic, and biological, is a unique contribution of SK. This perspective establishes a more fluid relationship among these levels, free from rigid hierarchies.

Furthermore, the coevolution of the human brain and supercomplex systems reflects a vision of the human brain as an entity that not only observes and modifies complex systems but also evolves in parallel with them, in a continuous process of complexification. This deep integration between human beings and the systems they observe is a defining characteristic of SK, distinct from other theories that consider humans as merely external observers.

It is possible that SK's paradigm is unique in its approach to complexity, precisely because other frameworks tend toward simplification by focusing on partial or unilateral aspects. Its emphasis on intrasystem behaviors in conjunction with intersystem interactions, combinatorics, the power of fluctuations, and nonlinearity may position it as a viable option for understanding phenomena that other approaches fail to fully capture. There is an evident “healthy circularity” between theory and intervention, demonstrating that this paradigm can address pressing issues not only in science but also in social and planetary challenges that demand urgent solutions.

We reiterate that SK not only describes complexity but also integrates its study into the very process of observation and modeling. This represents a paradigm shift: it is no longer just about describing systems with multiple interactions but about recognizing that supercomplexity necessarily involves the active intervention of the observer in its measurement and comprehension. This aligns it more closely with developments in quantum mechanics and epistemology, where the description of a phenomenon is not independent of the framework in which it is studied.

A common risk in many complexity approaches is that everything becomes a "catch-all" where any phenomenon is simply labeled as "complex" without meaningful distinctions. However, in SK, supercomplexity has emerged as a distinct category, separate from complexity itself, which we aim to accompany with a new form of modeling and analysis.

The notion that many scientists remain in a "comfort zone" is supported by the way certain dynamics operate within the scientific community. Power structures, funding sources, and prevailing paradigms often encourage specialization and the repetition of previously accepted concepts, making it more difficult to introduce novel paradigms like SK. Traditional theoretical frameworks offer apparent solidity and security; in contrast, embracing complexity and the interconnection of multiple systems, as proposed by SK, requires a profound shift in the mindset of philosophers (of science), scientists, and complexity scholars. For many, this would mean accepting uncertainty and ambiguity as inherent parts of their theories, something uncomfortable and contrary to the comfort provided by linearity and determinism.

Adopting SK requires rethinking the role of the scientist, not just as a data collector but as a cartographer of relative and temporary behaviors, inviting a departure from purely descriptive and monocausal approaches. This shift, though necessary and enriching, may face resistance in a community accustomed to operating under established paradigms and subject to the inertia of its own systems. This space, often overpopulated with critics disguised as disseminators, suffers from a lack of creative developers capable of proposing and constructing authentic solutions.

We are driven by the knowledge that there are hundreds of specialists from diverse scientific, philosophical, and technological fields who may approach our proposal to enrich it. We are fully aware that when presenting innovative ideas, the processes of validation and acceptance are challenging and require a long period of maturation. We are open to improving the theory based on valid critiques, verifiable facts, and new discoveries, rather than arguments based on any form of “principle of authority.”

Finally, the essence of SK has proven to be more than just a theoretical framework, it has become a thought matrix, a fundamental organizer of our perception of reality. Once the principles of SK are embraced, it becomes almost inevitable to see the world through them. It is as if SK not only offers tools to describe, predict, and modify systems but also reconfigures the way the observer-developer interprets and acts. SK organizes thought in such a way that, upon adopting its principles, one begins to see reality as an interconnected network of energetic variables, where temporal connectivity and structural morphology are not merely components but active forces shaping each system. In this sense, SK not only proposes a new way of doing science and philosophy but also a new way of being in the world.

Ultimately, history is written by those who dare to challenge the prevailing paradigms.

CHAPTER ONE

THE CURRENT SITUATION OF COMPLEXITY THEORIES

Complexity in general, and Complexity Theories in particular, have garnered increasing interest and generated a significant volume of research. They are highly compelling for understanding the current reality and its challenges. Since the middle of the last century, academics, scientists, and philosophers have proposed multiple definitions of complexity across various fields such as physics, biology, mathematics, sociology, philosophy, and economics, among others. Complexity emerged as an interdisciplinary and multifaceted topic, initially characterized by recognizing the influence of multiple factors and the unpredictability in many natural and social systems, challenging any linear, simplistic, and binary explanation and acknowledging the intricate nature of systems and phenomena. By the mid-20th century, Complexity Theories began to develop as an alternative to the monocausal, simplified, and deterministic explanations that dominated the science of that time. These explanations were founded on the principles of mechanism, reductionism, and empiricism. However, as some neuroscientists point out today, it was extremely difficult, even for experienced researchers, to think in terms of "complexity," since the norm in academic circles was linear thinking, based on cause (monocausality) and effect (determinism) relationships. This approach, along with inherent bias, was often invisible and unquestioned.[1]

[1] For more on this point, see: Montealegre Torres, Jorge Luis. "Corrientes de la Complejidad: Convergencias y divergencias," Revista de Ciencias Sociales, vol. 26, no. 1, 2020. Also in: Cardozo Brum, Myriam. Las ciencias sociales y el problema de la complejidad. Argumentos (Méx.) [online]. 2011, vol. 24, no. 67.

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Initially, "complexity" did not have the polysemic, multivocal, multidimensional, and multifaceted character that it is attributed today. While there was always some agreement on the etymology of the complex as "that which is joined and interlaced," there are dozens of definitions of complexity, and this is an issue that has continually evolved depending on the context and theoretical and disciplinary frameworks. Thus, we can refer to a kind of 'babelization' in the conceptualization of complexity, probably explained by the fact that it has been approached from various disciplines, each with its own perspective and specific definition. This is compounded by the action of numerous complexologists, who retouch, redefine, and postulate their own definitions, scopes, and characterizations. In this way, different theoretical stances have amalgamated and associated, in some cases with cooperative fluidity and semantic compatibility, and in others, through intense debates about the validity of their proposals and profound discrepancies with others. In these cases, disciplinary biases have hampered agreements and consensus. On the other hand, the recurrence to specific excerpts and combinations made from them have been marked by the influence of "schools" of thought, which have exerted control, imposition, and surveillance over the contents that their members must follow. This control has represented an additional factor weakening the possibilities for dialogue and enrichment among different approaches.[2]

[2] It should be noted that there are researchers who have been interested in exploring the ancient historical pillars, distant sources of inspiration for complex thought. In Greek philosophy, figures like Leucippus, Democritus, Heraclitus, and Aristotle, as well as Anaxagoras, Empedocles, Epicurus, and Plotinus, from their positions on the constituent elements of the universe, the importance of energy, and the problem of change. Eastern thought, including Buddhism, Taoism, and Zen, also has points of convergence with Complexity Theories in terms of their focus on interconnection, combinatorial dynamics, and the understanding of complex systems.

It is not our intention to provide an exhaustive inventory of all the sources of inspiration, concepts, approaches, and disciplines that have contributed to the foundational development of Complexity Theories. However, it is important to highlight some of the most relevant contributions, among which are:

- The Theory of Evolution.
- The Laws of Thermodynamics.
- Quantum Mechanics and the Uncertainty Principle.
- General Systems Theory.
- Cybernetics.
- Constructivism.
- Network Theories.
- Information Theory.
- Neurosciences.
- Chaos Theory.[3]

Perhaps it is General Systems Theory, through its proposal to explain reality by the interaction of different systems, one of the most influential sources in Complexity Theories. Authors such as Ludwig Von Bertalanffy, Heinz Von Foerster, Gregory Bateson, Humberto Maturana, Francisco Varela, and the Palo Alto School, among others, contributed essential foundations from this perspective.

Furthermore, the contributions of Henri Poincaré, Norbert Wiener, and Edward Lorenz, who explored how complex systems exhibit unpredictable behaviors and how small perturbations can

[3] Chaos Theory focuses on how small variations in initial conditions can lead to different and unpredictable future outcomes (the butterfly effect), even in deterministic systems. We, without discrediting its valuable contribution, believe that Chaos Theory has a more limited object than Complexity Theories in general, since it is confined to initial conditions, to dialectics between order and non-order, and to the constant search for patterns (fractals, for example) and the role of supposed attractors. This will be demonstrated in the present work.

generate disproportionate effects on the outcomes, cannot be overlooked. The work of mathematicians like Benoît Mandelbrot, who introduced the concept of fractals in the 1970s, also proved crucial for the development of these theories. Similarly, Stephen Wolfram stood out with his models of cellular automata, fundamental in the development of computational models applied to complexity.

Over the years, Complexity Theories have focused their study on three fundamental objects: 1) Complexity, understood as the language of the universe, characterized by inter-connection, unpredictability, and difficulty in being broken down into isolated parts; 2) Complex Systems, conceived as sets of interrelated elements that generate emergent properties and behaviors; and 3) Emergence in Complex Systems, which refers to the appearance of properties or behaviors that are not evident at the level of the individual components but arise from the interactions and relationships among the elements of the system as a whole. The study of these three objects seeks to understand the dynamics and behavior of complex systems across various disciplines, from philosophy and physics to biology, economics, and social sciences.

The study and application of complexity have attracted the attention of numerous academic institutions, research centers, and scientific communities around the world, which have developed and applied theories such as Complexity Sciences and Complex Thinking to address challenges arising in various fields, from physics and biology to social sciences and organizational management.

Evidence of this is the use of the complex paradigm, as an advanced transdisciplinary tool, by leading global companies, international organizations, and governments worldwide in various aspects of their respective tasks, consciously or unconsciously. The insight characteristic of a complex approach can be observed in the research on the most pressing problems of contemporary international order: the spread of global diseases; issues in local, national, regional, and global economic systems; cybersecurity and organized crime; the impact of climate change and environmental pollution; political-ethnic-religious armed conflicts; among others. Something similar occurs within national states when making decisions in complex systems, such as economic or political, which present multiple interconnected variables to consider. In many countries, these theories have a high impact and generate concrete outcomes, whether in the formulation of public policies, technological innovation, the development of educational perspectives, or the management of economic and biological systems in general.

The achievements of these disruptive and overcoming theories can be divided into theoretical and applied. Complexity Theories can claim as theoretical achievements: an expansion and a new integrality in the scientific perspective; the interconnection and relation among different phenomena and among the largest number of intervening variables; a greater openness to uncertainty and diversity; new descriptions, modeling, and algorithms of systems; the promotion of interdisciplinary practices; a combination of description and intervention on physical and biological events seeking solutions for the major problems affecting humanity. As for applied achievements, the list of areas where work has been done is extensive. As examples, we can mention: climate behavior, turbulences in energy flows, pattern formation in convection, self-organization in magnetic systems, nanotechnology and new materials, synchronization in coupled oscillators, thermodynamics of non-equilibrium systems, disease propagation networks, economic fluctuations in financial markets, behaviors of urban traffic, models in neural networks, population dynamics, health and educational programs, information spread in large communities, metabolic networks, gene regulation, species interactions, coevolution, formation of ecological niches, genomic and proteomic data.

The study of complexity has been led by paradigmatic figures who have left a significant mark on our understanding of complex systems, leading to two major approaches: Complex Thinking and the Sciences of Complexity. Historically, Complex Thinking preceded the Sciences of Complexity, developing from the 1970s. This stream, founded by Edgar Morin, emphasizes the interconnection and intricate nature of phenomena across various disciplines. Morin created an epistemology that challenges simplistic explanations and promotes an integrative and multidimensional view of knowledge, profoundly influencing fields such as education, sociology, and philosophy.

On the other hand, the Sciences of Complexity emerged in the 1980s with a scientific and mathematical focus on the study of complex systems and their emergent properties. This movement is closely associated with the Santa Fe Institute (SFI), founded in 1984 in New Mexico, USA. Among its founding members are J. Doyne Farmer, Murray Gell-Mann, John H. Holland, Melanie Mitchell, Stuart Kauffman, and Duncan Watts, who have explored phenomena such as emergence, self-organization, and attractors in nonlinear dynamic systems. The SFI has been a key point of interdisciplinary research, bringing together scientists from various areas to investigate how complex patterns arise from simple interactions.

Stuart Kauffman and his colleagues have played a crucial role in developing conceptual and mathematical models that explain the emergence and dynamics of complex adaptive systems. Along with collaborators like Geoffrey West and Brian Arthur, Kauffman has formulated theories on the emergence of life, evolutionary dynamics, and adaptive systems, impacting areas such as biology, economics, and network theory.

Both visions have had a significant global impact, influencing academic institutions, research centers, and organizations in various countries. Theories of Complex Thinking and the Sciences of Complexity have become key tools for rethinking contemporary problems in local and global contexts, influencing public policy formulation, technological innovation, and sustainable management.

Some have tried to simplify the disputes between these two visions as a debate between philosophers and mathematicians or between generalists and specialists. The former emphasize the importance of considering philosophical aspects and broader implications, that is, viewing complexity as an inherent property of the universe that unites and connects all systems. The latter, on the other hand, defend the need for solid mathematical frameworks to model and analyze complex systems, especially when they present emergences and novelties. The academic-theoretical debate between complexologists of Complex Thinking and those of the Sciences of Complexity highlights the lack of consensus regarding the object of study, foundational epistemologies, and methodologies. These differences include the role of the observer, the tools for description, and the perspectives for modeling complexity.

In the last thirty years, besides the disputes between the main approaches, a variety of methodologies have emerged such as System Dynamics, Complex Network Theory, Cellular Automata Theory, Evolutionary Game Theory, Complex Adaptive Systems, Agent-Based Simulation, and Ecology of the Mind. These are just a few examples of the visions and methodologies, which according to some researchers could add up to a hundred, that have contributed to the field of Complexity Theories.

While the diversity of perspectives within Complexity Theories offers advantages, such as the flexibility to adapt to a wide variety of systems in different fields and disciplines, it also fosters the integration of knowledge and perspectives from experts in various areas, allowing complex problems to be approached from multiple angles. However, this same diversity poses significant challenges, such as the difficulty in consolidating a coherent and unified theory and the lack of methodological standardization, which complicates the comparison and generalization of results and conclusions.[4]

After evaluating the significant achievements reached by Complexity Theories, it is important to reflect on some of their general limitations. One of the recurring challenges is the diversity of perspectives regarding the object of study: does it focus on complexity as a phenomenon in itself, on complex systems, or on emergence processes? This diversity enriches the field, but it also poses challenges in establishing a unified framework. Moreover, there is a profusion of abstract descriptors

[4] There have been numerous attempts to unify complexity theories, aiming to develop a coherent and systematic view of the field. One of the notable approaches is the Theory of Complex Systems, which integrates concepts and principles shared by different systems. It starts from the premise that many systems, regardless of their nature, share common characteristics such as self-organization, feedback, adaptability, and emergence. This theoretical framework seeks to be applicable to multiple disciplines and phenomena, facilitating interdisciplinary understanding and providing tools to model, describe, and analyze complex systems from integrative and multi-scale perspectives. Similar to SK, it promotes points of convergence between disparate theories, aspiring to address complexity in a systematic and unified way, but it could highlight specific aspects where SK offers a more innovative perspective.

attempting to capture its functionality and behavior, which in some cases complicates the integration between intra and intersystem analyses.

Another pending issue is the absence of a taxonomy that organizes the different types of complexity within each system, which could provide greater conceptual and practical clarity. In many cases, the modeling performed in the field of Complexity Theories tends to focus on specific aspects of the systems, either through tools such as mathematical equations and computational models or through conceptual and qualitative approaches. While both perspectives contribute valuable knowledge, the challenge lies in combining these approaches to achieve a more integrated understanding of complex systems. Lastly, the limited connection with social and planetary problems in certain theoretical frameworks restricts their practical applicability, although several researchers are already working to bridge this gap.

Although both frameworks -Complex Thinking and the Sciences of Complexity- are powerful in their respective fields, they tend to operate in a fragmented manner and with descriptors that can be considered reductionist in certain contexts. This fragmentation of knowledge hinders an integrative understanding of complex systems and limits progress toward a conceptual and methodological synthesis that encompasses complexity in all its dimensions.

Complex Thinking, primarily developed by Edgar Morin, has influenced the way complexity is understood from a transdisciplinary perspective. However, it faces criticisms and has certain limitations:

1. Lack of mathematical and scientific formalization: Complex Thinking lacks a formal framework that allows for the operationalization of its concepts, complicating the modeling and analysis of complex systems.

2. Excessive philosophical abstraction: Descriptions tend to be theoretical and narrative, with a number of categories that can be excessive and not very applicable (indecidability, for example).

3. Lack of distinction within complexity: It fails to clearly differentiate between types of complex systems or levels of analysis, leading to excessive generalizations.

On the other hand, the Sciences of Complexity, although they have offered new ways of understanding complex systems, also present limitations.

1. Lack of precise definition: There is no clear and universally accepted concept of what constitutes the Sciences of Complexity, making them appear more fragmented than complex.

2. Lack of clarity in the object of study and generalizations: It is not clearly established what a "complex system" is or what components or properties characterize it.

3. Lack of empirical contrast: Although mathematical modeling and simulation are useful, they often prove too speculative and detached from real observable phenomena.

4. Lack of distinction between scales and levels of complexity: The absence of differentiation between levels and types of complexity can lead to reductionism.

5. Reduction to chaos: The relationship with Chaos Theory has focused its approach on the description of chaotic phenomena, which has limited its ability to address complexity from a more integral and multidimensional perspective.

6. Neglect of the stable structure of systems: Behaviors that are resistant and tense in systems have been overlooked.

7. Fragmented mathematical and computational modeling: The lack of a coherent theoretical line prevents the development

of mathematical models and algorithms that are consistently applicable.

Many actions have been attempted to overcome this situation of void and anomie, of confrontation and gap between the Sciences of Complexity and Complex Thinking; spaces and events have been created to discuss and find agreements, but none of these actions, we believe, have been sufficient to overcome the unlimited multiplication of concepts, approaches, and methodologies that do nothing but weaken the theory, preventing it from being practical and useful in addressing pressing social and planetary issues.

There is a vast number of complexologists who believe that their own construction of complexity is the best and superior to any other. This exaltation of egos crystallizes into a kind of institutional mosaicism where each framework sees other theoretical frameworks as rivals, leading to cognitive closure and the generation of partisanship. That said, it is important to recognize that science has always been evolving and new paradigms emerge in response to the perceived limits of existing theories. While some complexologists may resist changes, others may see them as opportunities to address questions and challenges that were previously inaccessible or misunderstood.[5]

[5] An interesting event took place in 2021 with the awarding of the Nobel Prizes in Physics. This event highlighted how the scope of the term "Complexity Theories" can be interpreted so broadly that two research projects with seemingly divergent objects and methodologies were presented by some science communicators as advances within the same theoretical framework. This reflects the possible inconsistencies in the public perception of this field and the need for greater conceptual precision.

CHAPTER TWO

NEW ATTITUDES FOR RETHINKING COMPLEXITY

A genuine understanding of complexity must challenge any process of indoctrination or manipulation that imposes a predefined vision of reality, the universe, life, or personal fulfillment projects. This includes all areas: knowledge, creativity, and the pursuit of truth. The abandonment of a critical perspective in favor of a socially imposed illusion inevitably leads to the loss of the subject's autonomy.

It is essential to use the tools of philosophy, science, and technology to unmask manipulations and distortions of reality, especially those imposed by religious, political, social, or cultural fundamentalisms. This effort requires courage, intellectual honesty, and a willingness to unlearn deeply ingrained beliefs that limit our ability to think freely.

Furthermore, strength is needed to face potential social sanctions, such as isolation or rejection by those who cling to conservative or fanatical positions. Assuming this responsibility means being open to a new stance toward reality, even when it challenges the norms imposed by society.

A) RESISTANCE, LIMITATIONS, AND OBSTACLES TO RETHINKING COMPLEXITY

Our beliefs and mental limitations act as the very boundaries of our symbolic universe, defining what we can understand and explore. If the physical universe is vast in itself, our access to its complexity and depth depends on our ability to transcend those beliefs. Freeing ourselves from these limitations not only expands our symbolic understanding but also enables us to approach complexity from a more open and transformative perspective.[6] The obstacles to understanding, accepting, and committing to a new paradigm and knowledge of complexity include:

1. **Limitations of Current Modes of Thinking**: The proliferation of certain modes of thinking, binary, singular, light, linear, and simplifying, so prevalent today, hinders the emergence of knowledge about complexity. These tendencies privilege simple, linear, or monocausal explanations, making it difficult to grasp the interconnection and emergent dynamics inherent to complex systems. Additionally, cultural norms and deeply ingrained societal beliefs act as barriers that reinforce these reductionist perspectives, particularly when new approaches challenge traditional conceptions of knowledge and reality. Overcoming these limitations requires a profound shift in our way of thinking, adopting an open and integrative mindset willing to explore the richness of the interrelations that define complexity.[7]

2. **Limitations in the Conception of Science:** Traditional science, with its emphasis on the search for universal laws and constants, faces significant limitations when addressing complex systems, which are characterized by multiple, dynamic,

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[6] Within the framework of SK, science can be interpreted as a particular form of belief. However, unlike other forms of belief, science is grounded in the continuous flow of data and evidence, aspiring, at least in its ideal, to free itself from biases, preconceived ideas, partisan axiologies, and arguments from authority. This dynamic and relational approach allows science to evolve and self-correct, striving to describe and understand the complexity of the universe and life with the openness inherent to its method.

[7] Extreme political and religious ideologies tend to simplify and distort reality to fit their agendas. This phenomenon often involves rejecting complexity in favor of partial and Manichean narratives that promote the polarization of issues and the demonization of opposing groups. Fundamentalist theocracies are a prime example of these dynamics, having contributed in recent decades to the rise of terrorism as a persistent global threat. This kind of ideologization and radicalization hinders the possibility of adopting knowledge and practices based on complexity, both of which are essential for addressing contemporary challenges in a comprehensive and sustainable manner.

and ever-changing causality. Reductionist approaches, which break systems down into manageable parts, operate under the assumption that the whole is merely the sum of its parts. This leads to static and deterministic models that assume fixed rules, ignoring the dynamic and emergent interactions that define complex systems. Understanding complexity requires a paradigm shift: rather than breaking systems into isolated elements, we must focus on the relationships and interactions that give them their unique character. Systems cannot be fully understood without considering how their components interact, intertwine, and transform one another. More than merely accepting complexity, we must adopt it as the starting point for exploring reality, recognizing that only through this paradigm can we grasp the richness and depth of complex phenomena.

3. **Limitations of Human Cognitive Capacity**: Our brain is predisposed to simplification and categorization, which makes it difficult to grasp the inherent complexity of systems. To facilitate understanding, communication, and immediate action, we tend to divide reality into well-defined objects and clear categories. While this fragmentation is useful in everyday contexts, it also limits our ability to perceive the continuity and underlying interconnection in the processes of the universe and life itself. For this reason, complexity, and especially supercomplexity, are considered counterintuitive and counter-cerebral. Studies in neuroscience have identified biases such as confirmation bias, which leads us to prioritize information that reinforces our preexisting beliefs while ignoring data that could reveal greater complexity. Likewise, apophenia, or our tendency to seek patterns even where none exist, can project unfounded correlations and oversimplify realities that are much richer. While these cognitive mechanisms have been useful from an

evolutionary perspective, they can act as barriers to understanding and accepting the dynamic interconnection of complex systems. Overcoming these limitations requires a conscious effort to question our beliefs, open ourselves to broader perspectives, and adopt tools that allow us to navigate complexity more effectively, integrating both intuition and analytical reasoning in our thinking.

4. **Limitations Among Complexity Scholars**: Some representatives within the field of Complexity Theories have exhibited sectarian attitudes, a lack of dialogue, arrogance, and intolerance, which has caused discomfort and alienation among those interested in the paradigm. This impoverishment is reflected in the repetition of disconnected analyses that fail to achieve integration. There are resistances, for example, to including the microsystem of particles or to utilizing discoveries from neuroscience, data science, network theory, or simulations, among others. Complexity scholars, alongside scientists and philosophers, should abandon approaches based on absolute certainties and instead adopt paradigms that combine provisional certainties with uncertainties that are progressively unveiled.
5. **Cultural and Institutional Limitations:** Academic educational structures and scientific funding systems are often designed to reward traditional and reductionist approaches. The rigidity of these institutions can hinder the adoption of innovative paradigms. Curricular frameworks and scientific evaluation mechanisms, being oriented toward specialization and knowledge fragmentation, do not always encourage an interdisciplinary vision or the integration of multiple levels of complexity. This institutional resistance contributes to the perpetuation of static models and makes it difficult to advance toward more integrative and dynamic paradigms.

B) THE CONSTRUCTION OF A COMPLEX ATTITUDE

The complexity of the universe, life, and our brain demands not only a cognitive response but also a deep commitment to an open and flexible stance. This attitude involves confronting the most challenging questions through creative and effective solutions, avoiding simplistic or monocausal explanations. Instead of relying on single causes, it is about considering a wide range of variables, integrating different perspectives to build a more enriching and systemic vision.

Adopting a complex attitude means accepting the coexistence of the linear, repetitive, and uniform with the novel, emergent, and exceptional. This paradigm invites us to recognize both regularities and unexpected disruptions, valuing the diversity and dynamism of phenomena. In doing so, it fosters a more flexible understanding of reality, based on a dynamic balance that prioritizes the observation of interconnections rather than fragmenting events or phenomena. This approach entails avoiding the hypostatization of intuitions, refraining from forcing descriptions to fit into predetermined narratives, resisting the bias of apophenia, and challenging reassuring but oversimplified answers.

This attitude challenges traditional educational and scientific models, advocating for a shift toward a more integrative and systemic vision. It is not only about observing systems or macrosystems but also about reflecting on the cognitive processes of researchers and human developers. This requires tools that enable the visualization of the multi-scalar interrelations of complex systems, as well as algorithms capable of detecting fluctuations, non-constants, and dynamic behaviors. These tools will become essential for advancing the understanding and modeling of complex systems.

Finally, understanding multicausality means recognizing that any event or transformation results from a web of interactions, feedback loops, and interdependencies. This perspective transcends the reductionist view that fragments reality into isolated causes, allowing for the mapping and modeling of these complex interactions. In this way, it becomes possible to capture the convergence of different energy flows, structural morphologies, and temporal connectivities, offering a more comprehensive and transformative understanding of reality.

CHAPTER THREE

THE PRINCIPLES OF SUPERCOMPLEX KNOWLEDGE

A new era of growth in complex knowledge and actions begins with the evolution and transformation of concepts, models, objectives, and the spaces constructed by the observer-developer. Complexity Theories must evolve toward a more advanced and developed state. Development implies accepting that we must enter a more mature and comprehensive stage of study compared to the initial theories of complexity. For this reason, we propose, in principle, and submit for consideration by the scientific community at large, the following principles of Supercomplex Knowledge (SK):

FIRST PRINCIPLE: The object of study is complex systems, analyzed through the triad of their components: energy flows, structural morphology, and temporal connectivity.

The object of study of Supercomplex Knowledge (SK) is complex systems[8] in all their multidimensionality. From this

[8] It should be noted that, to some extent, a system is a construct of the observer. The reality we know, dynamic and complex, is only observable through the systems we construct to make it intelligible. We prefer the concept of "system" over "organization" or "field." A semantic discussion is unnecessary since the debate should be morphological, that is, related to the content of understanding. Morin favors the concept of "organization" and conceives it as a continuous process of self-organization and development, where adaptability and evolution are key components. He highlights how biological and social systems maintain and renew their structure through internal processes. This conceptualization is not replaced by the one we present throughout this work, but we believe that the concept of "system," under our understanding and complex behavioral delimitation, is broader and more integrative. In Quantum Field Theory (QFT), "fields" are fundamental entities that permeate all space and time. These quantum fields are treated as the basic constituents of reality, with particles being mere excitations or manifestations of these fields. This conception may be more encompassing and fundamental than that of "system," as traditionally understood. The fact is that we include microparticle macrosystems, and almost the entirety of complex behaviors mentioned align with the dynamic proposal of "fields" in the aforementioned theory

position, we understand systems as real or abstract[9] units of energy management in dynamic and evolutionary interaction with their structural morphologies in a search for self-preservation over time through temporal connectivity strategies. It is, therefore, a three-dimensional, interdependent, circular, dynamic, and evolutionary interaction between energy, space, and time.

The SK's conception of complex systems as dynamic and interdependent units managing energy, space, and time resonates with contemporary research such as Complex Network Theory[10], which explores connectivity and emergent dynamics in interconnected systems; Systems Biology[11], which addresses organisms as networks of energetic and temporal interaction; and Agent-Based Modeling[12], which replicates evolutionary and adaptive processes. These studies reinforce the SK's three-dimensional and evolutionary perspective, linking its postulates with current interdisciplinary approaches.

For this reason, energy flows, in any of their expressions, structural morphology (space), and temporal connectivity strategies (time), activation and deactivation of functions and the internal or external temporal contact of the system, are the three fundamental dimensions for understanding, describing, intervening in, and/or modeling any type of system. These

[9] An abstract complex system is a conceptual representation of a real complex system, used to study and understand key aspects of that system in a more manageable and accessible way. These abstract models allow for the analysis and simulation of system behavior, the identification of multicausal relationships, and the recognition of emergent characteristics. Additionally, they provide a foundation for formulating and testing hypotheses about how the real system functions. In this way, abstract complex systems and real complex systems should not be considered separate entities but rather as mutually complementary

[10] Barabási, Albert-László. Network Science. Cambridge University Press, 2016.

[11] Kitano, Hiroaki. "Systems Biology: A Brief Overview." Science, vol. 295, no. 5560, 2002.

[12] Gilbert, Nigel, and Klaus G. Troitzsch. Simulation for the Social Scientist. Open University Press, 2005.

dimensions are central to describing the universe and life and explaining the continuity-unity and the diversity of all systems.[13]
The three components are versatile and encompassing:

1. **Energy Flows:** Represent the active dynamics that traverse the system, including physical movements, information transfers, levels of activity or concentration, emotional transformations, and even value exchanges in economic systems. Energy flows can be constant or fluctuating and are key to understanding how change and adaptation occur within a system.[14]
2. **Structural Morphology:** Encompasses the configurations, behaviors, rules, and structures that organize or limit energy flows, both among the internal elements of the system and with the external systems it interacts with. This morphology can be physical (shapes and material structures), conceptual (models and theories), symbolic (languages and meanings), or digital (networks and algorithms), reflecting how the system is organized and evolves.
3. **Temporal Connectivity:** Reflects the synchronization, duration, sequencing, and coordination of interactions within the system, as well as with other systems in exchange, over time. It involves how relationships in a system develop, are maintained, or are transformed over time, affecting the stability and dynamism of the system. Temporal connectivity is essential

[13] Is the SK compatible with the approach of 'quantum gravity'? Quantum gravity seeks to unify general relativity, which describes gravity on a large scale, with quantum mechanics, which explains subatomic phenomena. Similarly, the SK proposes that complexity arises from the dynamic and bidirectional interaction between macroscopic systems, microparticles, and biological systems, offering a framework that could integrate gravitational effects with quantum principles. In particular, the idea in the SK that space and time are both concrete and abstract aligns with the notion in quantum gravity that spacetime is not a static background but behaves dynamically and can be affected by quantum fluctuations.
[14] Matter is not considered a separate fundamental component within complex systems but is understood as a manifestation or 'presentation' of energy. From this perspective, matter is a condensed form of energy that adopts various structural configurations depending on energetic interactions and its space-time context.

to capturing both permanence and change in the system's dynamics.[15]

From our perspective, it is essential to consider the components of complex systems to achieve a comprehensive understanding of the phenomenon. However, the analysis should not be limited to certain behaviors but must address the integrality of the system, including the changes that occur both internally and in its interaction with other systems.[16]

Energy flows are essential for the functioning and behavior of systems as they drive processes and interactions and participate in the creation of structures and in their self-regulation. In this sense, energy[17] is necessary for transporting, processing, and transmitting information. These transfers can occur linearly, but they can also follow topological, fractal, radial, reticular, spiral, toroidal, and other forms, which adds

[15] Albert Einstein's Theory of Relativity emphasizes the inseparable interrelation between space and time, forming a unified entity known as 'spacetime.' This concept aligns with our paradigm, which considers time and space as dimensions that influence the dynamics of complex systems. However, while Relativity focuses on cosmological and gravitational phenomena, our proposed interconnection applies to a broad range of systems, including microscopic, biological, and technological ones. On the other hand, we share with Norbert Wiener's Cybernetics, centered on control and feedback systems, an emphasis on regulation and self-organization within systems. Yet, while Cybernetics focuses on more traditional control mechanisms, our framework incorporates a more integral approach that includes energy and temporal connectivity. Finally, Ilya Prigogine's theories on dissipative structures offer points of convergence in their analysis of energy flows. However, we extend this perspective by considering the interactions between multiple complex systems and their ability to reconfigure themselves through temporal connectivity and modifications in their structural morphologies.

[16] The reductive approach to emergent properties and behavioral patterns can lead to overlooking the importance of understanding the constituent parts and their interactions. Therefore, we consider it necessary to observe the properties of complex systems, including the nature and relationships of their components, to achieve a more comprehensive perspective. Another issue arises when the internal elements of the system (intrasystem) are described without considering the exchange systems (entresystems).

[17] It is important to remember that energy is not directly observable; rather, we perceive it through its effects on space and objects. For example, light and heat are manifestations of electromagnetic energy, and the movement of objects is a consequence of kinetic energy. Thus, although we cannot see energy itself, we constantly perceive it through its multiple everyday manifestations.

enormous complexity to the study of these systems. These interactions and superpositions of energy flows, characterized by an intrinsic circularity, make these systems diverse, change and evolve over time, and expand and interconnect in space.[18] Focusing on details, we consider that energy flows are shaped by two fundamental events: first, the interaction between different types of energy, which can generate unique energetic manifestations with direct impacts on the functioning of the involved systems and their connected systems; second, the resistance imposed by structural morphologies and connectivity strategies, which delimit and define the possible trajectories of these energy flows.

For the SK, energy is conceived from its combinatory capacity that allows the interaction between different vibrational frequencies, within a process of superposition and synchronization, in which emergent properties, new phenomena, or stability within a system appear. It is visualized as a continuous and multidimensional flow that traverses and connects the different elements of the system and the systems among themselves.[19]

We consider information as a form of energy that acts actively on the structure of a complex system, shaping its form

[18] We do not conceive of a linearity between energy forms, as the intertwining of different expressions of energy generates an inherent circularity. Systems that emerge from the coupling of preexisting systems can recombine with the original systems of the interaction, thereby increasing the overall complexity.

[19] The SK's conception of energy as a multidimensional and combinatory flow resonates with various authors and research studies. Ilya Prigogine studied the role of energy in the formation of dissipative structures, while David Bohm linked it to the implicate order and universal connectivity. Hermann Haken explored its role in the self-organization of systems through synergy. Albert-László Barabási analyzed how energy drives interactions in complex networks. Fritz-Albert Popp highlighted the importance of light energy in biological processes through bio-photons. Nikola Tesla understood energy as the foundation of resonance and vibrational frequencies, and Benoît Mandelbrot connected energetic dynamics with emerging fractal patterns. These perspectives reinforce the SK’s idea of energy as a central agent in complex systems.

and organization. This perspective underscores the capacity of information to interact and shape the internal structures of such systems, evidencing its crucial role in the dynamics and evolution of the same. Information constitutes the synthesis of what occurs in terms of energy, space, and time in a given system. It facilitates communication and energy transfer, provides the context for understanding spatial and temporal interactions, and arises as a result of these interactions.

Regarding energy flows, we can outline a brief evolution of them. From the first cosmic fluctuations in this universe, the different modalities of energy have driven the creation and evolution of the quantum world. The primordial energy released generated the first subatomic particles such as quarks and electrons, which gave rise to the microparticle macrosystem. As the universe cooled, nuclear energy allowed the formation of the first atoms, stabilizing light elements such as hydrogen and helium. Subsequently, gravitational energy attracted these atoms, leading to the formation of stars and galaxies through nuclear fusion, where gravitational interactions dominate the large-scale structure of the universe.

On Earth, chemical energy and solar energy were crucial for the emergence of life when molecules began to self-organize into the first cells. Life evolved from simple unicellular organisms to more complex multicellular systems, using metabolic energy for sustenance and adaptation.[20]

Throughout human history, the ability to transform mechanical and electrical energy allowed the development of technologies. Finally, in the modern era, the digital revolution introduced digital energy and information processing as crucial

[20] For the SK, evolution does not follow a direct or progressive line. Instead, it is a dynamic and multifaceted process where adaptations and changes arise through trials, errors, and constant readjustments in response to a changing intersystem.

energetic modalities. With the emergence of Artificial Intelligence and cyber-analog systems, human capabilities to manipulate energy and manage information have reached new heights, generating an increasingly deep interconnection between biological and technological systems.[21]

For the SK, energy flows adopt a functional morphology that is the result of the combination of various energies and the ways in which these move and circulate through the space of the complex system. Generally, this movement manifests in turbulence, undulations, vortices, laminar flows, convection, diffusion, and oscillations, which are indicative of the internal energetic dynamics.[22]

The interaction between structural spatial morphology and functional energetic morphology in the SK is essential for understanding the complete dynamics of the complex system. Structural spatial morphology refers to the arrangement and physical organization of the components of the system in space. This includes the shape, size, distribution, and connection between the different parts of the system.

On the other hand, functional energetic morphology focuses on how energy flows and is distributed throughout the system, manifesting in behaviors such as turbulence, undulations, vortices, laminar flows, convection, diffusion, and oscillations. These energetic behaviors are crucial for the functions and processes that occur within the system.

[21] In more detail, different types of energy and different modalities of energy flows can be discussed. Among the types of energy, we have: kinetic, potential, gravitational potential, elastic potential, chemical potential, thermal, electrical, magnetic, electromagnetic, strong and weak nuclear, radiant, sound, mechanical, chemical, ionization, dark energy, among others. Energy flows are processes in which energy is transferred or transformed from one type to another. Examples include: radiation, conduction, convection, turbulence, geothermal, hydrodynamic, wind, solar, and tidal energy.

[22] These movements are characteristic of the macroscopic and biological macrosystems, but not of the microparticle macrosystem.

The interaction between both morphologies is bidirectional and dynamic: The physical arrangement of the system can facilitate or limit certain types of energy movements. For example, a structure with narrow channels may favor laminar flows, while more complex geometries can generate turbulence and vortices. The topology and spatial connectivity determine the possible routes for energy movement.

The behaviors of energy flows can, in turn, modify the physical structure of the system. For example, in natural systems, the flow of water can erode the terrain and alter its morphology. In biological systems, the transport of nutrients and energetic signals can influence structural growth and development.

Thermal energy is one of the most prevalent forms of energy on Earth and has a significant impact on the movement behaviors observed in macroscopic and biological systems. In addition to thermal energy, various other forms of energy play crucial roles in changes within complex systems, either competing with or interacting with thermal energy. Some of the most significant include chemical, kinetic, gravitational potential, electromagnetic, nuclear, and electrical energy, among others.

Each of these forms of energy can compete with or interact with thermal energy in complex systems. Often, these forms of energy do not act in isolation but transform into one another through various processes, generating significant changes in the structure, behavior, and dynamics of systems. The ability of complex systems to store, transform, and distribute these energies is fundamental to their evolution and adaptation.

Moreover, structural morphologies precisely determine how the components of systems are organized, their possibilities for interaction, and how energy flows through them. In this sense, energy flows can only be expressed according to the system's morphological structure; however, energy circulation, as a result of the plasticity and adaptability of systems, can lead to modifications in these structures.

From the SK perspective, we avoid adopting unilateral positions that simplify the structural-morphological complexity of the universe. This includes both the idea of perfect symmetry, as proposed by supersymmetry theory (SUSY), and absolute unpredictability, characteristic of chaos theory. While both perspectives have provided valuable tools for understanding structural aspects of nature, reducing the universe to only one of these visions may lead us to overlook its true richness. Reality appears to exist within a more dynamic spectrum, in which symmetries and asymmetries coexist (along with symmetries with asymmetries and asymmetries with symmetries), inter-penetrating and depending on the level of analysis or the system being considered.

Regarding structural morphologies, these appear with different predominances in complex systems and, in many cases, are superimposed:

- Linear, dependence. Linear structures suggest a sequence where each step depends on the previous one;
- Reticular, cooperation and competition. Networks allow interaction between various nodes that may collaborate or compete for resources;
- Arborescent, hierarchical dependence. Here, lower nodes depend on the upper ones;
- Topological, cooperation. This structural form is ideal for connecting nodes in a way that optimizes their functions;
- Laminar, superposition, and relational depth. These represent interpenetrated layers of systems, processes, or

variables that do not cancel each other out but rather mutually enhance or create tension.

- Radial, central dependence. In this case, the central node provides and/or controls resources for the peripheral nodes;
- Fractal, autonomy and dependence. These structures typically operate autonomously at different scales but maintain dependence through repetitive forms;
- Spiral, cyclical dynamics. Generally, they express continuous feedback cycles;
- Toroidal, cyclical interdependence. Continuous cycles where all nodes are interconnected in such a way that the flow never stops;
- Hexagonal, cooperation. These structures maximize spatial and resource efficiency;
- Cylindrical, continuous flow. This structure promotes the continuous flow of resources and/or information;
- Pentagonal, balance and stability. Ideal structures for balancing functions or roles.[23]

The evolution of structural morphologies in complex systems does not follow a linear arrow leading to progressively more complex forms. On the contrary, it is a dynamic and non-linear process, where universal principles interact with spontaneous reorganizations triggered by novel events, internal or external fluctuations, and new combinations among system elements. This dual nature, which combines common structural behaviors

[23] When two different structural morphologies meet, the result is not necessarily the emergence of a new morphology that is a perfect combination of both, nor the simple dominance of one over the other. The outcome is contingent on the internal dynamics of the system, the amount and type of energy available, the properties of temporal connectivity, and the adaptability of each morphology to its specific context. The emergence of a new morphology or the dominance of an existing one will depend on how these variables are configured.

with emergent and contextual responses, helps explain how a system can adapt, regress, or even coexist in overlapping states.[24]

It is worth clarifying that in complex systems, although multiple structural morphologies coexist, one may become predominant within a system. However, this predominance is neither absolute nor permanent, as systems operate within margins of fluctuation that allow the emergence of new configurations in response to internal or external changes. These margins ensure the adaptability of the system, enabling dynamic transitions between predominant forms depending on the system's evolution.

On the other hand, temporal connectivity refers to both the sequences of processes necessary for the system's functioning and the way it interacts with other systems. This may include cycles of communication, phases of growth or contraction, among other possible dynamics in the search for preservation and efficiency.[25]

In the SK, it could be said that temporal connectivity and energy flows maintain a bidirectional relationship. On the one hand, energy flows determine certain temporal behaviors, supporting the idea that temporal connectivity is an epiphenomenon of the energy component. On the other hand, once these temporal behaviors are established, temporal connectivity can, in turn, influence the modulation of energy and

[24] The transition from a radial structure to a networked one, as might be observed in a family business, does not follow a predetermined trajectory but rather results from a combination of factors such as the need to manage increasing commitments, the preparedness of its members, and the delegation of responsibilities. In this process, 'advances' and 'setbacks' are not contradictory but rather manifestations of constant adaptation. Previous forms do not completely disappear; instead, they remain as active layers within the structure, ready to reorganize in response to new circumstances.

[25] In other words, energy is the driving force behind all interactions and changes; space provides the physical and structural context where these interactions occur, and time sets the pace and sequence of the processes of change and evolution.

the structural reorganization of systems, acting as an active factor in the generation of complexity.[26]

We note that among the three components, there is a dynamic, circular, and evolutionary interaction. From our approach, we maintain that each of these organizational and fluctuating possibilities presents certain tendencies and associated behaviors: cooperation, competition, dependence, and various symbiotic relationships, among others.

Although we will address these concepts in greater depth later, we can already cite some examples where the interaction between energy flows, structural morphology, and temporal connectivity is clearly observed.

For instance, we ask what type of interaction between the components of a complex system, such as a plant, must occur for it to adopt a reticular form (a network-like structure) or a rhizomatic form (an interconnected underground branching structure). In fact, there is a specific interaction between energy flows and structural morphology that channels its development in one of these directions.

It can be observed that when contact systems (solar, water, and biological through nutrients) and their energy flows are distributed more homogeneously and consistently, the interactions favor a network structure, where the plant expands its growth horizontally or in multiple directions in a balanced manner. This "distributed" energy allows the creation of strong connections between different parts of the system, optimizing resource absorption from multiple points. In contrast, if energy flows, such as nutrients or water, are concentrated in specific areas, the plant develops a rhizomatic structure, extending its

[26] Fritz-Albert Popp demonstrated that biophoton emissions (light energy) in biological systems are closely related to temporal rhythms, suggesting a reciprocal interaction between energy and temporality in the regulation of the process.

rhizomes toward those areas rich in energy. This form enables it to take advantage of concentrated energy points, such as localized nutrient reserves in the soil or underground water sources.

In conclusion: if the structural morphology of the plant responds to a uniform distribution of resources, each part of the plant would grow synergistically and connected, in a radial or reticular manner, maximizing exposure to external resources (sunlight, aerial space, or soil, etc.). In this case, the plant seeks to maximize its interaction with other systems in multiple directions. However, if the structure is rhizomatic, it is due to the need to be more adaptive in the search for resources. The plant would develop underground extensions that act as "energy explorers," adapting to concentrated energy flows in certain areas. This more decentralized and modular expansion allows the plant to colonize spaces with nutrient patches, connecting disparate parts of the underground system with the available energy.[27]

We can provide other examples where the interaction between these three components is visualized:

- **Spiral galaxies:** The structural morphology of spiral galaxies (such as the Milky Way) facilitates an efficient flow of energy along their arms. The energy flows here include the distribution of gas, stars, and dust, which dynamically redistribute in spirals due to the angular momentum generated by the galaxy's rotation. This distribution balances gravitational forces, maintaining the stability of the structure. Temporal connectivity is observed in how gravitational interactions and stellar motion

[27] Relevant sources on this topic include: 1) Stiefkens, Laura Beatriz, et al. Morfología Vegetal: Guía de Trabajos Prácticos. Sima Editora, 2017. 2) Mesa López, Neftalí. Manual de Morfología Vegetal Externa. Grupo de Investigación en Genética y Biotecnología Vegetal y Microbiana de la Universidad del Tolima (GEBIUT), Universidad del Tolima, 2020.

generate cycles of star formation, where energy transforms and is reused over millions of years.

- **Hexagonal cells in beehives:** The hexagonal structural morphology optimizes the use of space and materials. In terms of energy flows, bees minimize energy expenditure in building the hive, as the hexagon has the best area-to-perimeter ratio, requiring less wax to store the maximum amount of honey. Temporal connectivity is manifested in the synchronization of cell construction, which follows a coordinated format among the bees to ensure that the structure grows efficiently and remains stable over time.
- **Plant cell walls:** In plants, cell walls are composed of cellulose, which provides both rigidity and flexibility. This allows for optimal structural support while facilitating the exchange of nutrients and water, fundamental aspects of energy flows related to photosynthesis. Temporal connectivity is evident in the daily cycle of photosynthesis, where plants rhythmically harness solar energy, storing and distributing the products of photosynthesis for growth throughout the day and night.
- **Nuclear fusion reactors (Tokamak):** In fusion reactors such as the Tokamak, the toroidal structural morphology is essential for confining plasma at extreme temperatures. The energy flows here involve the movement of highly energetic particles within the plasma, where the Tokamak's shape ensures that the plasma remains confined for longer, reducing energy loss. Temporal connectivity is crucial, as fusion can only be sustained for short periods during which temperature and pressure conditions are optimal for ions to fuse and release energy.

These examples demonstrate how energy flows, structural morphology, and temporal connectivity interact in both natural and artificial systems, optimizing energy efficiency and ensuring the stability and evolution of systems over time.[28]

Finally, we must understand the following characteristics of systems as necessary corollaries after the delimitation of our object of study:

1. **There is nothing in the universe that is not part of a system:**

Every system is constituted by a network of dynamic and evolutionary interactions between components. The parts are not understood in isolation but rather in terms of their internal and external relationships. The universe is composed of an infinity of interconnected systems that form and evolve at various levels of complexity. Every particle, object, or observable structure is part of a larger system, whether it be a physical, biological, or conceptual system. No entity exists outside a system, which implies that there are no islands of isolation in the observable reality.

2. **All systems are connected or interwoven:**

This principle highlights that systems do not exist independently. Instead, they are interconnected and interwoven with one another, generating dynamic interactions that determine their behavior. Imbrication is a key concept in SK, as it encompasses both the interrelation between systems and the overlapping of their components and functions. For example, the biological system is interwoven with the macroscopic system, and both interact with the microparticle system.

[28] The SK, by defining the components of a complex system, makes a qualitative leap that allows transitioning from an intuitive understanding to one based on concrete and measurable facts. This distinction is crucial because the SK does not merely describe emergent properties but seeks a solid foundation in well-defined interactions, as some approaches in Complexity Theories do. The definition of the components (energy flows, structural morphologies, and temporal connectivity) in the SK provides a more rigorous framework, less reliant on intuitions and abstract generalizations.

3. There are no voids between systems; no medium, no environment, no surroundings:
This principle states that there are no empty spaces or physical or conceptual separations between systems. The "medium" or "environment" is not external to systems; rather, it is part of a continuous network of interrelations. Energy, information, and matter flow without voids, meaning that every system affects and is affected by others in a complex web of mutual influences.

4. Closed systems can only be conceived in abstract terms:
Although in certain theoretical contexts or simplified models it may be useful to refer to closed systems (where there is no exchange of energy, matter, or information with the external environment), such systems do not exist in reality. All real systems are open to interactions with their intersystem. Closed systems can only be thought of as abstractions or theoretical models used to simplify analysis in certain disciplines.

5. Systems are constructions of the human observer-developer system:
This principle underscores the constructivist nature of SK. Systems, as we perceive and understand them, are the result of the cognitive, technological, and conceptual tools that humans have developed to observe, describe, and model reality. This implies that the understanding of any system is a relative construction, based on the interaction between the observer and the object of study.

SECOND PRINCIPLE: In complex systems, there is a coexistence of stabilizing functions, synchronous co-emergences, and sequential asymmetric fluctuations (progressive innovations).

For Supercomplex Knowledge (SK), complex systems exhibit a dynamic coexistence between stabilizing functions, synchronous co-emergences, and sequential asymmetric fluctuations, which allows for an understanding of both stability and transformation. Stabilizing actions ensure the functional organization of the system by synchronizing energy flows and optimizing its structure in the present. At the same time, synchronous convergences organize components and functions in simultaneous interaction, achieving cohesive and stable morphological configurations. On the other hand, sequential asymmetric fluctuations introduce progressive imbalances, reorganizing structural morphologies and reconfiguring temporal connectivities, giving rise to innovations and adaptive evolutions. It is through this dynamic combination, where energy flows are efficiently managed, structures are constantly reorganized, and temporalities intertwine, that functional stability and adaptive change are balanced, ensuring the evolution and survival of the system.[29]

These interactive behaviors, which at times may seem opposed, stability and emergence, compression and expansion, synchronicity and sequentiality, not only coexist but are the

[29] Energy flows are the driving force that sustains and maintains complex systems, constantly adjusting to synchronize and distribute efficiently. This process generates dynamic equilibria that ensure temporal stability. At the same time, structural morphology reflects how a system's components are spatially organized, facilitating synchronous interactions that optimize functionality and strengthen system cohesion. Temporal connectivity adds an evolutionary dimension, describing how interactions within a system change and reorganize over time. Asymmetrical sequential fluctuations disrupt established equilibria, introducing progressive imbalances that reconfigure both structures and temporal connections, driving innovations and evolutionary adaptations.

drivers of the evolution, transformation, and continuity of complex systems. In a stochastic and evolutionary process, emergent phenomena arise that explain the complexity of the universe and life on a large scale. When organizing these behaviors according to their role in complex systems, three major groups can be identified: producers of provisional stability, drivers of synchronous co-emergences, and generators of asymmetric fluctuations that lead to sequential emergencies and progressive innovations.

Processes that generate provisional stability are fundamental for establishing structures and temporary balances in complex systems. Examples include crystallization, where atoms organize into three-dimensional lattice networks; the stable configuration of planetary orbits through gravitational interactions; ocean currents, which regulate climate and transport nutrients; and tree growth rings, which reveal cyclical adaptation to interactions with other systems. In the biological realm, this can be seen in the self-organized stability of the DNA double helix, in cell membranes that maintain functional integrity, and in bone structures, whose combination of compactness and porosity ensures resistance and adaptability.

Behaviors that drive synchronous co-emergences promote self-organization and systemic efficiency, allowing for constant interactions. Examples of these processes include bird flocks, whose coordinated flight reduces energy consumption and improves aerodynamics, and transport networks in leaves, which optimize the distribution of nutrients and water. In ecosystems, trophic networks allow for stable interaction between producers, consumers, and decomposers, while coral reef structures and root systems with mycorrhizae promote adaptability and cooperation, optimizing the generation of complex habitats. At the neuronal level, the plasticity of networks allows for the functional reorganization of the nervous system, facilitating learning and memory in response to stimuli from other systems.

Generators of asymmetric fluctuations and sequential emergencies introduce fundamental transformations that drive evolutionary innovations. Due to the effects of cosmic inflation, they gave rise to the first structures of this universe. The phase transitions during the early cooling of the cosmos allowed for the appearance of particles and finely tuned structures, while primordial nucleosynthesis led to the formation of the first light elements that served as the foundation for the creation of initial stars. In later stages, the asymmetry between matter and antimatter, quantum tunneling, and nuclear fusion enabled the emergence of heavy elements and the release of energy.

In the biological domain, autocatalysis and genetic mutations play crucial roles in the emergence of new life forms, while speciation and adaptation facilitate the diversification and optimization of organisms. At the cognitive and cultural level, coevolutionary processes have generated networks of complex interdependence, where consciousness, cognition, and learning enabled the emergence of new social structures and technologies. In the field of artificial intelligence, phenomena such as convolutional neural networks, generative adversarial networks, and deep learning represent contemporary examples of progressive innovations in complex systems, revolutionizing the capacity for processing and knowledge generation.

In this way, complex systems develop through a dynamic balance between provisional stability, synchronous co-emergences, and asymmetric fluctuations, leading to the continuous generation of new structures and behaviors. These processes demonstrate that the complexity of the universe cannot be reduced to linear or simplified patterns, as it arises from the dynamic interaction between energy flows, structural morphologies, and temporal connectivities, both within systems and in their multi-scale interactions.

From the perspective of SK, the anomalies and fluctuations observed in complex systems do not represent ruptures within a rigid framework, but rather natural manifestations of the continuous interplay between stability, synchronization, and emergence. Rather than interpreting them as exceptions or deviations, the SK understands them as intrinsic expressions of supercomplex dynamics, where multiple processes interact across different levels and scales. This implies that what appears anomalous is merely the result of fluctuating combinatorial processes that generate emergent behaviors and new adaptive adjustments. Thus, phenomena that classical science interprets as irregularities can instead be understood as components of a continuous, evolutionary process, one in which complexity unfolds through a tapestry of provisional stability, synchronous co-emergences, and asymmetric fluctuations, integrating both transient patterns and profound transformations.

From this perspective, the universe is conceived as an interconnected fabric of energy, interactions, and evolution, where the causes of complexity intertwine, generating the rich diversity that characterizes our reality. The SK paradigm allows us to capture these profound interactions, showing that the evolution, transformation, and continuity of complex systems depend on this dynamic interplay between stability, synchronization, and progressive imbalance.[30]

[30] Complexity arises from this dynamic balance between stability and change, where energy flows, morphological structures, and temporal connections not only coexist but intertwine in an evolutionary and stochastic process. Thus, complex systems continuously generate and transform new forms and functions, challenging any attempt to reduce them to linear or simplified patterns. This interconnected fabric of energy, space, and time explains the rich

THIRD PRINCIPLE: Three Macrosystems Coexist -Microparticles, Macroscopic, and Biological- With Their Corresponding Levels of Complexity and Overlapping Interactions.

From our perspective, three overlapping types of macrosystems describe reality: microparticles, macroscopic, and biological. For Supercomplex Knowledge (SK), each of these macrosystems presents a distinct modality and evolution of complexity, which precisely defines the macrosystem itself.

- **Microparticle Macrosystem:** This macrosystem encompasses the subatomic particles that make up matter, such as electrons, protons, neutrons, and their fundamental components (quarks, gluons, etc.), as well as the most elementary particles that interact according to quantum physics laws. It also includes bosons, such as the photon (light particles) and the Higgs boson, which grants mass to other particles.
- **Macroscopic Macrosystem:** This macrosystem begins where atoms combine to form molecules and larger structures. It also includes non-biological organisms (inert materials), geological structures (planets, mountains), and extends to planetary and galactic scales, covering everything from everyday objects, terrestrial formations, planetary systems, galaxies, and galactic clusters.
- **Biological Macrosystem:** This macrosystem starts at the cellular level, with the first life forms based on prokaryotic or eukaryotic cells, encompassing the biochemistry essential for life (DNA, proteins, metabolism). It includes unicellular and multicellular organisms, extending to global ecosystems, with biolo-

diversity of reality, showing how the forces of stability and emergence, synchrony and sequentiality combine to shape the evolution, transformation, and continuity of complex systems in the universe and in life.

gical interactions ranging from cellular processes to the behavior of entire communities and ecosystems, including non-human and human animals and all their productions.

The three macrosystems, microparticles, macroscopic, and biological, represent different levels of complexity, each with its own set of characteristics that organize reality in a particular way.[31] Therefore, macrosystems are not independent entities but emergent results of a continuous and multiscalar process, where the dynamics between stability, synchronization, and progressive imbalance generate the diversity and complexity observed in the universe.

The microparticle macrosystem is characterized by quantum complexity, where energy interactions are non-deterministic and probabilistic, governed by phenomena such as superposition and quantum entanglement. At this level, particles do not have a fixed structural morphology, and their behaviors are stochastic and highly unpredictable, making them the most abstract and dynamic level of complexity, in constant interaction with the other macrosystems.

In the macroscopic macrosystem, complexity deviates from classical physics laws and emerges when these systems self-organize and generate complex, unpredictable behaviors, such as the formation of galaxies, atmospheric phenomena, or the combination of chemical elements.

In the biological macrosystem, complexity centers on adaptation and evolution, always strategic and therefore innovative, of living organisms. Metabolic energy flows allow organisms to stay alive, grow, and reproduce, managing their survival possibilities through interactions between energy flows, structural morphologies, and temporal connectivity.

[31] This classification is developed in more detail in chapter six.

Each macrosystem also has a foundational event. In the microparticle macrosystem, this event is cosmic inflation, a rapid and multiversal expansion process that gave rise to elementary particles and the conditions necessary for the formation of observable reality. More than an absolute starting point, the universe emerges as part of a broader dynamic of quantum fluctuations and energy expansion.The macroscopic macrosystem is marked by the formation of stars and galaxies, structures that shaped the universe as we observe it today. The biological macrosystem begins with the emergence of cellular replication and life, marking the appearance of biological systems capable of evolving and adapting, leading to even greater levels of organization and complexity in the universe. Each of these events represents crucial milestones in the progression of complexity in the universe, from the smallest particles to life itself.

Now, we consider that the boundaries between these macrosystems are not strict, and overlapping and transitional areas can be observed among them, with diffuse limits and phenomena influenced by multiple levels of complexity. In other words, there exists a dynamic, bidirectional triple overlap between the three macrosystems, making them far more complex and interconnected. Therefore, the study of one level of complexity often requires understanding and tools from another.[32]

Notwithstanding this, we must state that, in general, it has been the macroscopic macrosystem (physics and chemistry, excluding biology) that has dominated the disaggregation of complexity descriptors, in our view, as a result of the logical

[32] We consider that each of the three general macrosystems corresponds to a specific type of complexity: the microparticle macrosystem and Cuanticomplexity; the macroscopic macrosystem and Macrocomplexity; the biological macrosystem and Biocomplexity.

development of science and the evolution of observation and measurement instruments. For this reason, beyond the existence of shared descriptors due to the previously mentioned overlaps and interconnections, we propose specific descriptors for each macrosystem, tailored to the nature of each one.

As we will see later, SK proposes energetic, spatial, and temporal descriptors to describe complexity in each macro-system. In this sense, specific descriptors are presented, such as those linked to entanglement, superposition, and decoherence in the microparticle macrosystem. In the biological macrosystem, as we will see, complexity is shaped by functions of autonomy, metabolism, reproduction, cognition (consciousness), and learning (computation, mapping, and timing). From this perspective, it becomes clear that a single definition of complexity is impossible, as it consists of different predominant modalities of energy and structure. In other words, it is only possible to measure levels of complexity within each macrosystem.

From our perspective, it is feasible to approach reality using and combining the mentioned systems, both within each macrosystem and at an inter-macrosystem level. This approach is based on the premise that complexity is inherently combinatorial and interdependent. Such a methodology facilitates a more fluid understanding of the nature of the numerous existing complex systems and promotes the adoption of interdisciplinary approaches. Furthermore, the integration of various systems provides an innovative framework essential for addressing today's global challenges, leveraging the expertise of different disciplines.

In the fourth principle, we will show how, in addition to the complexity inherent to each of these macrosystems, a new level of complexity must be added, Supercomplexity.

FOURTH PRINCIPLE: Supercomplexity Adds New Levels to Complexity Through the Overlapping of Macrosystems and Active Modification, Reconfigured Both Cognitively and Technologically by the Human Observer-Developer.

Another group of causes contributing to the formation of a new level of complexity, which we will call "supercomplexity," is the fact that macrosystems are overlapped, with areas of superposition and constant mutual influence. Additionally, the interventions of researchers in their efforts to modify, explain, or intervene in systems through maps and algorithms also contribute to the final formation of this "supercomplexity."

For Supercomplex Knowledge (SK), there are three modalities of complexity and two of supercomplexity.

Three Modalities of Complexity:

1. **Microcomplexity:** This is the quantum level, where complexity emerges from interactions between subatomic particles. Phenomena such as superposition and quantum entanglement are examples of how interactions at this level are probabilistic and non-deterministic, governed by the laws of quantum mechanics.
2. **Macrocomplexity:** This level includes large-scale systems, such as planets, stars, and galaxies. Classical physical processes like gravity and Newtonian physics are the main factors regulating interactions at this level. Examples of macroscopic complexity include climate systems, fluid dynamics, and the self-organization of physical systems such as stars.
3. **Biocomplexity:** At the biological level, complexity manifests through interactions between living organisms and their contact systems. Adaptation, evolution, metabolism, and

reproduction are some of the key behaviors at this level, driven by metabolic energy and interactions with other living beings and systems.

Two Levels of Supercomplexity:

First Level of Supercomplexity: The Triple Overlap.

At this level, there is an overlapping of the three macrosystems: microparticles, macroscopic, and biological. Here, emergent properties arise from the interaction between systems. For example, how quantum processes influence biological systems or how macroscopic factors (such as climate) affect life on Earth. This overlapping generates new behaviors that cannot be predicted simply by studying each system separately. The interaction between complex systems leads to emergent phenomena beyond the individual properties of each macrosystem.

Second Level of Supercomplexity: The Sum of the Triple Overlap + The Cognitive Functioning of the Brain + Technology (Techno-Engineering and Cyber-Analog Systems), Especially Deep Learning and Artificial Intelligence.

This level adds an additional dimension through the involvement of the human brain and advanced technology. The brain does not merely observe but actively modifies the complex systems it interacts with.On one hand, the human brain acts as an agent that feeds back and reconfigures systems, introducing a new layer of cognitive complexity. The human brain has the ability to reconfigure its own neural "wiring" as it interacts with complex systems. This neuroplasticity process allows humans not only to observe reality but also to change their perception and the tools they use to interact with it.[33]

On the other hand, advanced technology, such as cyber-analog systems and techno-engineering infrastructures, intervenes in complex system interactions. These systems combine technological and biological complexity, enabling the management and modification of biological, physical, and social systems through technology. An example would be artificial neural networks (deep learning), which directly impact biological and technological systems, helping to process large volumes of data and modify systemic behaviors in real-time.

Additionally, AI systems introduce a new mode of cybernetic emergence, where machine learning algorithms interact with biological and physical systems to generate new solutions, predictions, and interaction models that humans alone could not create. Here, technology and artificial intelligence enable new forms of interaction and system modification. Techno-engineering and cyber-analog systems allow complex systems to adapt and self-manage, adding a dynamic dimension of control and evolution to biological and physical systems, a dimension of supercomplexity.

SK redefines supercomplexity as a dynamic, expansive, and multidimensional process that goes beyond the observation of complex systems, incorporating active modification and cognitive and technological reconfiguration. This enables the visualization, and eventual modification, of new events, new

[33] The construction, prediction, and modification of supercomplex systems require an observer and developer who embraces and develops their own supercomplexity. In this sense, the subject must be aware of their own complex nature and their role as a multifaceted being interacting with various levels of reality. They must recognize that their identity, knowledge, and actions are deeply interconnected and interdependent with the surrounding macrosystems. Furthermore, they must accept that their reality is dynamic and in constant transformation, which implies the need to adapt and be flexible in their approaches and strategies.

combinations, and new circularities in the universe, life, and the human brain. This distinguishes it from traditional approaches to complexity by introducing the bidirectional and evolutionary interaction between the human brain, macrosystems, and advanced technological tools, creating an expansive paradigm that opens new possibilities for describing, predicting, and transforming systems. This is why SK establishes itself as an integrative and at the same time surpassing alternative to classical science, Complex Thought (Morin), and Complexity Sciences.

In contrast to classical science, SK argues that complex phenomena cannot always be reduced to universal constant laws. Many behaviors in the universe are stochastic and non-deterministic and require dynamic maps, not fixed patterns. Instead of seeking constants, SK aims to understand interrelationships and how systems evolve based on their interactions and considers that physical constants are not absolute but rather functional approximations dependent on measurement contexts and the level of interaction between systems. The introduction of noise, asymmetries, and non-linearity in real systems reveals that these constants are subject to variations.[34]

While classical science relies on fixed laws and patterns (such as the law of gravity or quantum constants), SK questions the permanence of these constants under extreme conditions or at unexplored scales. Additionally, it proposes maps that illustrate the evolution and emergent behavior of complex

[34] The idea that physical constants may depend on context is not new. The works of Barrow, Webb, Uzan, and Magueijo support this notion from both theoretical and observational physics. Additionally, the ideas of Dirac or Kaluza-Klein could further expand the discussion.

systems, surpassing the rigidity of deterministic models in classical science.[35]

Morin presents a more philosophical vision of complexity, whereas SK proposes that systems can be actively intervened in and modified through advanced technological tools. The ability to actively intervene in complex systems using AI and technology grants SK a scientific and technological applicability that Complex Thought does not fully contemplate.

Finally, SK expands Complexity Sciences by incorporating a relational and inter-systemic vision and distances itself from them due to their excessive dependence on sensitivity to initial conditions and pattern formation. SK questions the universal applicability of this premise, stating that many complex systems do not respond to initial sensitivity in a deterministic way. Additionally, it argues that the so-called patterns only emerge in specific cases and should not be considered a central descriptor of all systems. SK values the mathematical modeling of Complexity Sciences, but it also proposes that artificial intelligence, data science, neuroscience, and techno-engineering systems actively intervene in the real-time modification and optimization of complex systems.

FIFTH PRINCIPLE: Complex Multiscalar Constructivism is the Epistemological Foundation, and Probabilistic Multicausality is the Starting Point for a New Conception of Science.

[35] For example, Earth's movements are not caused by a single factor but result from the interaction between internal systems (such as the dynamics of Earth's core) and external influences (solar, lunar, and planetary gravitation). This reflects the systemic and interdependent nature of phenomena. Phenomena such as precession, nutation, or the Chandler wobble are dynamic and depend on variables that change over time, such as the redistribution of Earth's mass or external gravitational variations. This aligns with the SK's position that 'constants' are, in reality, relative and temporary. Finally, the systems involved (Earth, the Moon, the Sun, other planets) do not act in isolation; rather, their effects combine and overlap, generating complexity. This combinatorial paradigm reflects the core of the SK: understanding systems as interactive and dynamic networks.

Supercomplex Knowledge (SK) is based on a complex multiscalar constructivism, understood as a model that integrates a moderate constructivism or a "fact-checked constructivism" with the activity of the human brain and the use of advanced technologies to model and transform complex systems.

This constructivism acknowledges that our understanding and description of reality are built upon our experiences, interactions, cognitive abilities, and technological tools. Although this construction is inevitably conditioned by our limitations as observers, it is possible to identify consistent behaviors and recurring phenomena that suggest the existence of a relational framework that transcends individual perceptions. However, this 'objective reality' should not be understood as fixed, absolute, or independent of our interactions but as a dynamic, emergent, and multiscalar process that integrates our observations as part of the system it describes. There is no hidden order waiting to be discovered, but rather a reality that reconfigures itself. Epistemic uncertainty thus arises from ontological uncertainty.

From this perspective, reality is not merely an external object that we observe, but a network of interactions where observers and their observational tools play an active role in its configuration. This paradigm recognizes that any description is inherently tied to the interacting systems, the tools, and the scales used for observation.

When attempting to model or represent complex systems, our human tools, such as language, mathematics, advanced technologies, and cultural conventions, inevitably mediate these approximations. This process of mediation generates what SK refers to as "social formatting", a phenomenon in which our descriptions and models emerge from the shared historical, educational, and cultural context.[36]

The "distortion" through which we perceive reality implies that we observe something already filtered through our prior experiences and, in this sense, we make a selective framing. Within this approach, the perception of reality is not only filtered by prior experiences and individual cognitive structures but also by the network of interconnected systems in which those experiences are embedded. Each frame of reference adds an additional layer of meaning, amplifying or attenuating certain aspects of the perceived object. For instance, an everyday object may evoke different meanings depending on its cultural, emotional, or functional context and, consequently, will be perceived differently by two individuals, not only because they will register distinct aspects of the object but also because they will associate it with diverse networks of meaning and different frames of reference.

In this regard, multiscalar complex constructivism posits that perception is neither linear nor uniform but is instead constructed from multiple systemic interactions, where each relational node contributes to shaping what is perceived. This perspective not only underscores the subjectivity of the observer but also emphasizes the dynamic and evolving nature of perceptions. As the subject’s frames of reference expand, interpretations of the object may shift, revealing that reality is an active, relational construction in constant transformation.

[36] The notion of 'social formatting' aligns with the ideas of the sociology of scientific knowledge, as proposed by Bruno Latour and David Bloor, which highlight how social and cultural factors influence the construction of scientific theories. This concept also resonates with Michel Foucault's ideas on how discourses and cultural practices shape knowledge.

From a multiscalar perspective, the SK articulates interactions between different levels of complexity, microscopic, macroscopic, and biological, recognizing how these dynamics affect both the stability and emergence of systems.[37]

From a multiscalar perspective, SK articulates the interactions between different levels of complexity - microparticles, macroscopic, and biological- recognizing how these dynamics influence both stability and system emergence.

Complex multiscalar constructivism redefines these key concepts as inseparable components of complex systems, transcending the limitations of traditional deterministic paradigms and opening new possibilities for understanding, modeling, and transformation in science and technology. Additionally, this multiscalar constructivism considers that descriptive tools, such as algorithms, simulations, and four-dimensional maps, not only represent systematic frameworks but also modify them, establishing a circular relationship between knowledge, technology, and reality. It also acknowledges the duality between the concrete and the abstract in the interpretation of energetic, temporal, and spatial components. In this sense, energy, time, and space are abstract constructs that emerge from interactions. These categories not only organize thought but also facilitate effective intervention in

[37] This stance may encounter resistance from two fronts. First, from empiricist and realist approaches, which might challenge the emphasis on subjective and relational perception, arguing that it undermines the possibility of establishing universal and measurable laws. In response, multiscalar complex constructivism does not deny the existence of an objective reality but rather emphasizes that any measurement is mediated by networks of relationships and interconnected systems that modify what is observed. Second, from scientistic or deterministic complexity scholars, who might perceive the subjective and relational component as an unnecessary source of uncertainty. However, from the SK perspective, the aim is not to complicate for the sake of complicating but to acknowledge that systems are interdependent and that this interdependence influences how they are perceived, described, and modeled.

systems, positioning SK as a dynamic and innovative paradigm for addressing complexity.

From our perspective, the complexity of the universe, life, and the construction of knowledge coexist and coevolve in a feedback relationship. Therefore, knowledge and reality are naturally and fundamentally intertwined, making it essential to consider this entanglement to understand the nature of both.

This concept within SK implies an active stance in knowledge construction but goes beyond traditional constructivism by incorporating the complexity of systemic interactions. In SK, knowledge is not simply a mental or social construction but a dynamic process that emerges from the interaction between energy flows, structural morphologies, and temporal connectivity. This gives rise to a paradigm in which knowledge is seen as an interdependent network that evolves based on changes in its fundamental components.

The complex subject, as both observer and developer of complex systems, is part of that complexity, making it illusory to think that one can remain objective and "see from the outside" the supercomplexity of the universe and life. The observer is a product of the same complexity, and therefore, is "entangled", meaning their rationality, mappings, and interventions are constructions shaped by the contradictions between technology, self-awareness, social relations, symbolic structures, and biology. The "supercomplex" subject cannot separate themselves from the systems they study and develop, as they are an integral part of them. Their understanding and analysis are inherently limited and conditioned by their own nature and experience as a human being. This entanglement implies that their perceptions, theories, and interventions are influenced by their technological context, self-awareness capabilities, social relationships, cultural symbols, and biological factors.

The rationality of the complex subject is a dynamic construction that reflects the intersection of multiple dimensions of human existence, challenging the traditional notion of objectivity and emphasizing the need for approaches that recognize and address these interconnections. Paul Cilliers, in his book "Complexity and Postmodernism: Understanding Complex Systems," offers a critical perspective on the application and interpretation of complexity theories. Cilliers is skeptical of theories that claim to provide universal explanations for complex systems, advocating instead for contextual and situational approaches that acknowledge the particularities of each system, accepting that complete and fully objective knowledge is unattainable and that there are always limitations to our understanding of systems.

Under this perspective, we consider that the observer and the system are inseparable; as a consequence, knowledge is constructed through the interaction of individuals with systems, including the combinations we will explore later. Moreover, we must emphasize that we perceive reality through our cognitive filters, which are influenced by our experiences, histories, beliefs, and emotions. Thus, the constructive contribution of an individual will be marked by the systems that are most predominant in their life, making it logical that perspectives across different cultures and civilizations are so diverse.

Newton, Galileo, and Laplace saw an ordered world governed by causal and deterministic laws. They did not perceive the vast number of perturbations affecting a complex system, nor the fact that these perturbations vary at different scales. Instead of viewing the universe as a system ruled by universal constants, SK proposes models of reality that are in dynamic evolution, reflecting the stochastic, emergent, and changing nature of complex systems. This perspective is far more flexible and better suited to the diversity and multiscalarity of phenomena observed at different levels of reality, from microparticles to biological and technological systems.

Rather than breaking down phenomena to understand their basic components, SK posits that knowledge arises from the interrelation between complex systems. Therefore, it does not seek definitive formulas but rather networks of interaction and energy flows that account for how systems change and evolve.[38]

This is why SK not only adopts a constructivist stance but also introduces a critical distinction that goes beyond the general ideas of Von Foerster in Second-Order Cybernetics. For SK, the degree of construction by the observer varies depending on the macrosystem with which they are interacting. In other words, the observer's influence is not uniform across all systems: In macrosystem analysis, the observer's role varies, within the microparticle macrosystem, the act of observation directly influences the system's state; in the macroscopic macrosystem, its influence is smaller; and in biological systems, its impact depends on the complexity of the observed organism or system. This interaction highlights the inherent complexity of knowledge in relation to the systems being studied and developed.[39]

[38] Systems can rarely be fully explained through linear approaches that consider only one independent and one dependent variable. The interaction of multiple intervening variables is often key to understanding, describing, and predicting the behavior of these systems. In scientific research, combining interrelated variables can provide a richer and more accurate perspective, especially when dealing with phenomena that do not follow simple patterns.

[39] In the quantum realm, the act of observation can directly affect the state of the system. In macroscopic systems, the influence of observation may be less direct but still significant, particularly in scientific research contexts, where the formulation of theories and models can shape the direction of inquiry and the interpretation of data. In complex biological systems, the relationship between the observer and the system varies depending on the chosen approach. In biological research, the investigator's hypotheses can influence experimental

Comunidad del Saber Supercomplejo

In SK, the complexity of the universe and life coexist and evolve in a feedback relationship with the process of knowledge construction. We uphold a circular, active, and progressive co-construction between the human brain and the universe, where the brain not only interprets reality but also influences it through its perceptions, experiences, and thoughts. This dynamic relationship implies that knowledge acquisition is an active process that affects both the knowing subject and the object of knowledge. This paradigm also explains the plurality of interpretations across different cultures, as each individual perceives reality through the systems that dominate their life.

Finally, complex multiscalar constructivism proposes a dynamic way of building knowledge by considering the continuous interaction of the fundamental components of complex systems, which could generate both adherences and critiques from other perspectives, such as those of Kauffman or Morin.

Furthermore, SK promotes a science (descriptive, prescriptive, and developmental) built upon probabilistic multicausality, without negating the possibility of linear correlations in an initial construction of the intervening variables.

In the universe, indeed, many events and behaviors cannot be reduced or described through deterministic or linear laws but depend on probabilistic principles, as seen in quantum phenomena and the periodicity of comets, where multiple factors and small variations prevent exact predictions.

In this sense, complexity and stochasticity (as emphasized in SK) imply that there are far more events that cannot be described through exact laws than those that can. Deterministic

design and the interpretation of results. Moreover, when human beings are involved, the interaction between the observer and the system becomes even more intricate, as the system itself may respond to being observed.

chaos, turbulence in fluids, and stochastic fluctuations in complex dynamic systems are examples of this. Quantum fluctuations and nonlinear dynamics in systems such as meteorology and astrophysics show that, even though general laws exist, detailed predictions are extremely difficult or impossible.

The universe appears to operate on multiple levels with emergent and nonlinear behaviors, where universal laws can only be applied to limited domains and under ideal conditions. The probabilistic nature of complex systems is inherent and intrinsic and should not be understood as a result of a lack of knowledge or as a transitional stage toward discovering an underlying deterministic law. With this, the ideal of an 'exact' knowledge applicable to all reality is abandoned, accepting instead that, in many cases, knowledge is probabilistic and contingent. Heisenberg, Bohr, Lorenz, Prigogine, Kauffman, Maldonado, Smolin, and Bohm, among others, agree that probability is not an epistemological flaw but an ontological property of complex systems.

In summary, while universal laws provide tools to understand regular and predictable phenomena, there exists a vast variety of complex and stochastic systems whose nature cannot be fully captured by these laws. This recognition does not diminish the validity of scientific regularities but highlights the need to integrate probabilistic approaches and accept uncertainty as a key element in describing and modeling reality in its fullness.[40]

[40] While disciplinary fragmentation has been useful in deepening specific areas of study, it has come at the cost of limiting a holistic understanding of complex systems, where interactions between phenomena of various natures (physical, chemical, biological, social) are fundamental.

Currently, approaches that consider both deterministic and probabilistic aspects are beginning to be used.[41] From this latter perspective, the concept of stochasticity emerges to refer to systems or processes that are partially unpredictable but also partially probabilistic.

From the SK perspective, complexity lies between the deterministic and the probabilistic, without excluding the analysis of either aspect. Therefore, it is necessary to consider both linear and nonlinear interactions and to promote a science built upon probabilistic multicausality, a concept referring to the idea that complex events result from multiple causes interacting in a non-deterministic manner, each with different probabilities of occurrence. This paradigm recognizes that complex systems are influenced by a combination of factors and that the occurrence of certain events is not predictable with certainty but can be described through probabilities. There are many influencing factors, but in our view, the combination of energy flows along with the circular dynamics of structural morphologies plays a significant role. This prevents absolute certainty regarding expected outcomes but allows for probabilistic studies based on the nature of the systems under study.

It is necessary to clarify that in physical-chemical systems, this stochastic form of expression predominates, whereas in biological systems, behaviors are more structured around adaptive and survival mechanisms. In various biological systems, there is a combined and tensioned pursuit of survival and well-being, meaning the search for energy circulation and the construction of a structural morphology, interconnected with its species, that allows for more lasting survival and well-being. In other words, stochasticity is attenuated in these systems not only

[41] In areas such as Bayesian statistics or dynamic systems theory, hybrid models already exist.

due to internal conservation dynamics but also due to energy exchanges with various contact systems, fostering adaptability, interconnection, and evolution, where fluctuations are not seen as disturbances but as necessary inputs for a new order.[42]

From SK, the question arises as to whether technology and technologists have surpassed the constraints of classical science, given that they have a subject of study, a specific intentionality, and an inherently complex methodology. Technology has forced science to acknowledge that phenomena do not always follow simple trajectories and that patterns and regularities are only part of the equation in dynamic and complex systems. Wouldn't a 'technoscience', understood as a more suitable interface for constructing maps and algorithms, be a more fruitful alternative than focusing on the search for universal laws?

This technoscience would recognize that technologists do not merely describe reality but actively intervene in it, guided by specific purposes or intentions. The methodology is complex by nature, integrating multiple variables and incorporating the adaptability of models to new circumstances. Instead of imposing fixed rules, it would focus on creating maps, algorithms, and simulations that capture the richness of interactions and the contingency of complex systems, providing a more dynamic and practical understanding of reality.

Finally, a debate we did not wish to avoid is the relationship between SK and both structuralism and functionalism. In this regard, SK is neither structuralist nor functionalist but rather a surpassing of both approaches.

Structuralism focuses on the fixed and underlying relationships between the parts of a system, seeking to discover the

[42] SK believes that the concepts of order, equilibrium, and homeostasis are not adequate but rather reductive in explaining the dynamics of complex biological systems. The SK emphasizes the need to go beyond seeking stability, order, and equilibrium.

'structure' that determines the functioning of a whole. This perspective tends to freeze systems, searching for constant and universal patterns that, according to SK, do not accurately represent the true dynamics of complex systems. Instead, SK emphasizes fluidity and the continuous transformation of structures.

Functionalism, on the other hand, focuses on the functions that system parts perform to maintain stability and cohesion. It remains centered on the idea that systems organize around maintaining equilibrium and functional coherence. SK surpasses functionalism by integrating the notions of stochasticity, probabilism, and the emergence of new functions that are not solely oriented toward stability. While functionalism seeks to explain how system parts collaborate to maintain coherence, SK posits that instability, fluctuation, and emergent change are fundamental to the evolution of systems. Not all interactions within a system have a clear or necessary function for its equilibrium; some may even lead to its radical transformation or dissolution.

SK proposes that systems cannot be fully understood from either a structuralist or functionalist perspective, as both tend to emphasize regularity, predictability, and permanence. Instead, SK introduces the idea that systems are dynamic processes in which structure and function are emergent results of energy and temporal interactions. Rather than studying only the relationships between parts (as in structuralism) or the functions they fulfill (as in functionalism), SK focuses on how energy flows and temporal connectivity generate morphological changes. That is, the relationship between structure and function is circular and stochastic. Structure and function co-determine and co-evolve. Structural changes can lead to new functions, and emerging functions can, in turn, feedback and modify the structure. This view aligns with the idea that both structure and function are emergent temporal configurations within a constant flow of energy and information. It is a far more dynamic vision that acknowledges the crucial role of nonlinear fluctuations in the transformation of systems.

SIXTH PRINCIPLE: The modeling of complex systems is multidimensional, aiming at the construction of 'maps' and algorithms for description, prediction, and intervention.

SK studies systems in their multidimensionality through mathematical, computational, and conceptual (which can be analogical in the case of the biological macrosystem and its derived systems) modeling, adapting methodologies to the specificities of each macrosystem or system, ultimately leading to the development of maps that enable the design of algorithms for description, prediction, and intervention.[43]

From our perspective, it is possible to study systems in their multidimensionality through mathematical, computational, and conceptual modeling. The diversity of complex systems, as we

[43] For example, the biological macrosystem requires different techniques for description and intervention compared to the other macrosystems. The continuity and autonomy of living systems necessitate particular methodologies for approach by the human observer-developer in terms of developing strategies and complex tools such as the construction of broad descriptions, maps, and algorithms. As an example, we can mention the work carried out since 1960 by Jane Goodall with a tribe of chimpanzees, which demonstrated the importance of observation in their daily habitat and concluded that chimpanzees possess distinct personalities, with complex relationships of friendship and rivalry. In this way, an entire psychology and sociology of chimpanzees emerged in their complexity. In this study, the construction of broad and detailed descriptions of the social interactions and behaviors of chimpanzees in their natural habitat was fundamental. Researchers must employ prolonged and detailed observation techniques to gather data on social relationships, group hierarchies, play dynamics, and other behaviors. Additionally, creating maps that represent the social structure of the chimpanzee community and the modes of interaction between individuals is essential.

have pointed out, necessitates adapting the methodological approach to the characteristics of each macrosystem to achieve a comprehensive understanding of each modality of complexity. Therefore, the use of different modeling approaches according to the system being addressed results in the elaboration of a specific map, defined discretionarily and strategically according to the research objective, allowing the study of systems in interaction and, eventually, intervention through algorithms.[44]

From a mathematical approach, complex systems can be described through equations or systems of equations that represent the relationships between different variables within the system. These mathematical models can be linear or nonlinear, discrete or continuous, deterministic or stochastic (or a combination of both), depending on the characteristics of the system being represented. The construction of a mathematical model involves the representation of numerical and quantitative relationships between variables using equations and numerical expressions.

On the other hand, the construction of a linguistic conceptual model involves the representation of abstract concepts and their relationships using natural language and/or conceptual symbolism. This entails creating an abstract model in which the system's parts and their interactions and relationships are represented, potentially including diagrams, schemes, conceptual maps, flow networks, and other visual methods to depict the system's components and interactions. This type of modeling is useful for visualizing systems and is commonly applied in disciplines such as biology, psychology, and sociology. It is

[44] It is true that a strategic attitude is necessary to avoid contaminating descriptions with human criteria, but it is essential to acknowledge that it is impossible not to do so in interventions.

crucial for achieving a comprehensive understanding of systems as a whole and facilitating interdisciplinary interactions.

Additionally, computational modeling relies on the use of computer simulations to represent the system and its interactions. This approach employs algorithms and computer programs to simulate system behavior based on predefined rules. Generally, this type of modeling is used to study complex systems in real time and conduct virtual experiments.[45]

Furthermore, it is possible to approach the dimensions of complex systems in an analogical, metaphorical, or symbolic manner. In this sense, energy can be used as a metaphor or symbolic representation to describe the dynamics and driving force behind complex systems. This energy could refer to information, underlying forces, or influences that guide the behavior and transformations within the system. Similarly, space and time can also be utilized as metaphors or symbolic representations to describe aspects of complex systems. Symbolic space could refer to conceptual dimensions or fields of action, while symbolic time might denote evolution or change in a more abstract sense.

It is essential to recognize that there are different levels of study: descriptive, predictive, and intervention-based. Descriptive methodologies focus on the analysis and characterization of a system without interfering with it; here, algorithms and maps are employed to better understand a problem or situation and

[45] From the SK, we maintain that the approach to complex systems cannot be limited to a single methodology of description or measurement. We recognize that systems are interdependent and exhibit multiple levels of organization and emergence, which necessitates the integration of mathematical, conceptual, and computational approaches to capture their various aspects. These methods not only can coexist but must be applied strategically, adapting to the particularities of each system and the specific descriptive needs in this pursuit of comprehensive understanding. The combination of mathematical descriptions with linguistic and conceptual representations allows for the preservation of energy continuity and its relationship with the dimensions of space and time, thus offering a more complete and profound perspective.

identify trends. The goal of predictive tools is to anticipate future states or behaviors of a complex system. Intervention methodologies, in turn, aim to solve problems or modify specific situations. In this case, direct action is observed, intended to alter the course of a process or phenomenon.

To develop effective strategies for description, prediction, and intervention, it is necessary to construct strategic maps and algorithms tailored to the needs of the researcher.[46]

MAPS

We understand maps as visual representations intended to display the interconnections and inherent relationships among the elements that make up complex systems. These maps can vary in complexity, ranging from simple forms to more detailed presentations, depending on the complexity of the system being analyzed. In such maps, each component is symbolized as a node

[46] The simple act of tossing a coin exposes the interconnection of multiple systems and dismantles the illusion that a phenomenon can be explained through fixed constants. What appears to be a mechanical gesture is, in reality, the result of the simultaneous interaction between the biological system of the thrower, with variables such as neuromotor coordination, prior experience, and physical and emotional state, among others, and the atmospheric system, where factors such as wind speed and direction, air pressure, and temperature subtly shape the object's trajectory at every instant. The coin's fall is not solely an effect of Earth's gravity but is also influenced by the texture, inclination, and elasticity of the impact surface, the coefficient of friction, and even the possibility of rebounds or slips, among other factors. At the same time, the technological system represented by the coin itself introduces further fluctuations: its mass, center of gravity, aerodynamics, and material composition generate dynamic responses that challenge any attempt at deterministic prediction. On an even larger scale, the planetary system adds influences that, while imperceptible in daily life, remain present, ranging from Earth's rotation to subtle electromagnetic or gravitational interactions. Trapped within this web of interdependencies, the coin never follows an identical path, disproving the idea of absolute reproducibility under seemingly similar conditions. Classical science, in its pursuit of universal laws, is unable to account for this multiplicity of factors and their combinatory effects. The SK, on the other hand, enables the construction of 'maps' to describe the phenomenon in its entirety, not merely by identifying isolated variables but by modeling their spatial interactions and temporal evolution. With the aid of advanced sensors and artificial intelligence algorithms, it becomes possible to capture and represent the real dynamics of these systems, transcending the fragmented vision of traditional thought and understanding complexity as a living fabric of connections in constant transformation.

or point, while the relationships between these elements are represented through lines or arrows. These connections can manifest in various ways, encompassing linear relationships, influences, interdependencies, and feedback loops. Additionally, variable maps or diagrams can be qualitative, quantitative, or a combination of both, depending on their purpose and the information they aim to represent.[47]

The concept of dynamic maps implies a continuous updating of how we perceive reality, focusing on relationships rather than isolated entities. Maps are strategic tools designed to address the complexity of systems without attempting to encompass all their components. The SK asserts that, due to the multifaceted and stochastic nature of complex systems, it is neither possible nor practical to observe or address all systems and variables simultaneously. Therefore, maps in the SK are the result of a strategic selection, where certain key elements are prioritized based on three main criteria:

1. Prioritizing explanatory variables: Selecting variables that best explain the evolution and behavior of the complex system over time. This approach allows for a better understanding of how systems transform, interact, and adapt, generating emergent behaviors.

2. Focusing on intervention variables: Maps should identify variables that can be modified to enhance the system. These variables represent leverage points where interventions can positively impact the system's evolution, optimizing its functionality or adaptability.

[47] A qualitative map focuses on illustrating the relationships between variables and their modes of interaction without specifying numerical values. This methodology is useful for visualizing the flow of information without delving into numerical details. On the other hand, a quantitative map could include specific numerical values for the variables and their relationships, providing a more precise representation of data or specific calculations.

3. Aligning with instruments and methodology: Maps must consider variables for which the observer-developer (human) possesses the necessary methodological and technological tools to describe, model, and intervene in the system. This ensures that the knowledge generated is effective and applicable, avoiding variables where there is insufficient technical capacity for precise intervention.

Through these maps, the SK proposes a practical and flexible approach to analyzing complex systems. Rather than seeking a total explanation, which may be unattainable, the emphasis is placed on prioritizing variables that have the greatest impact on the description, prediction, and modification of the system. Thus, maps serve as strategic representations that guide intervention in complex systems, emphasizing what can be observed, modeled, and manipulated within the limits and capabilities of the observer.[48]

ALGORITHMS

On the other hand, an algorithm is a set of detailed instructions that a device can follow to solve a specific problem. Algorithms are fundamental as they enable the processing of large datasets and the generation of visualizations and explanatory models of these systems. Additionally, they allow for the representation and analysis of complex systems, providing valuable insights into their dynamic behavior. Algorithms supply the computational or logical tools necessary to analyze, process, or model the information contained in maps. This relationship

[48] Technologists, especially in fields such as artificial intelligence, data analysis, biomedicine, and ecology, use these 'maps' of interaction or networks to better understand their systems of study and develop more precise interventions. For example, in artificial intelligence and deep learning, neural network models are, in essence, dynamic maps of relationships and dependencies that represent the connections between multiple variables (nodes) and how they feedback and evolve.

allows for the extraction of properties and behaviors from the complex system described in the map, which, in turn, facilitates a deeper understanding and prediction of its dynamics.[49]

At the intrasystem level, maps and algorithms can identify and analyze complex internal dynamics, such as self-organization or energy resistance, offering insights into how to improve the system's efficiency and adaptability. At the inter/intersystem level, descriptors can be used to understand how different systems interact and influence each other. Maps can illustrate these interactions, while algorithms can predict how changes in one system might affect others. Descriptors enable the analysis of how these interactions influence the overall system dynamics, and algorithms can suggest ways to optimize these relationships for the system's benefit. By encompassing all three levels of analysis, it is possible to capture both the system's internal properties and its external relationships, which is essential for a comprehensive understanding of complex systems and their behavior.

OBSERVATION INSTRUMENTS

From another perspective, the SK promotes the use of new knowledge and technologies and, consequently, improved instruments for observation, detection, and measurement within the framework of constructing a new way of understanding complexity.

There are three generations of observation instruments for measuring and analyzing intervening variables in systems. In the first generation, each instrument measures only a single variable, providing isolated data. The second generation advan-

[49] The development of maps using SK descriptors allows for the visualization of how energy flows, structural morphologies, and temporal connectivity interact within a system or in the inter/intersystem dynamics.

ces by measuring groups of variables simultaneously, allowing for a richer understanding of systems but still limited in analyzing interactions. The third generation, however, focuses on measuring the simultaneous interaction between multiple variables, capturing the interdependent dynamics of complex systems.

For the SK, these third-generation instruments are the most suitable for analyzing complex systems, as they enable a deeper understanding of how variables influence each other within an interconnected system. This approach allows for a more precise capture of the essence of complex and supercomplex systems, which are characterized by their interactions and the emergence of new behaviors.

SCIENCES AND DISCIPLINES INVOLVED

The SK emphasizes the need to incorporate neuroscience, Artificial Intelligence, Big Data, and Deep Learning, among other essential tools, to develop and enrich its approach to the diversity of spaces and times in complex systems.[50] This paradigm could not only expand our theoretical understanding but also improve practical interventions across a variety of fields. Each of these fields provides unique tools and perspectives that facilitate the exploration and comprehension of super-complexity.

[50] In our team of developers, we have asked ourselves whether human observation systems would learn more from AI if it associated the intervention of numerous interdependent variables with foundational systems. We are aware that methodologies exist that aim to make this possibility viable. Cluster analysis is a technique used by AI algorithms to group variables or data into sets that are more similar to each other than to those of other groups (K-means, Hierarchical Clustering, DBSCAN). Similarly, deep neural networks and graph-based models can identify complex behaviors and nonlinear relationships between variables. Lastly, there are approaches and research lines in the field of Explainable AI (XAI) that share some commonalities with this idea.

In this regard, using neuroscience as a paradigm to address complex phenomena allows for a deeper understanding of how humans perceive, process, and act. Meanwhile, AI has the ability to model and simulate aspects of the supercomplex universe that exceed the direct comprehension of the human brain. It has become an indispensable tool for breaking down and analyzing an immense amount of physical, chemical, astronomical, and biological data. With its capacity to process information at an unimaginable speed compared to previous decades, AI can identify behaviors and correlations that would otherwise remain hidden. These technological advancements provide researchers with tools to explore complex scenarios and interactions, offering a more comprehensive understanding of processes across different levels of analysis that are otherwise difficult to observe directly. Closely linked to AI, Deep Learning can be used to uncover new relationships between data, thereby altering our current understanding of the universe and life. The identification of complex behaviors within vast datasets enables the exploration of new theories that were previously inconceivable due to the human inability to perceive large-scale correlations. Similarly, Big Data allows for a much more detailed comprehension and analysis of the universe to the extent that our very understanding of complex phenomena is clarified with the assistance of this tool. By collecting and analyzing extensive datasets on any complex phenomenon, such as climate change or species migration, we achieve a more thorough and substantial perception of these processes. This expanded comprehension reshapes and enriches our perception of the universe, influencing our broader understanding of reality itself.

DEVELOPERS

Considering the different approaches and skills required to handle complexity in system development, there are three levels of complex system developers. At the first level are scientists, at the second level are technoengineers, and at the third level are philosophers.

Scientists focus on the most technical and empirical aspects of complex system development. Their work may involve researching and applying scientific principles to understand and model the components and behaviors of systems.

Technoengineers apply engineering and technological knowledge to design, build, and maintain complex systems. This level centers on the practical application of theories and models developed by scientists to solve real-world problems and optimize system performance. This category includes systems analysts, software and hardware developers, and specialists in artificial intelligence, among others.

While traditional scientific approaches focus on intrasystemic analysis (what occurs within a system) or intersystemic analysis (the interaction between proximate systems), the philosophical gaze turns toward distal causal displacements. It seeks to grasp how local decisions generate effects in distant systems, how certain present adjustments result from remote evolutionary trajectories, and how the most profound transformations operate on temporal and spatial scales that often elude technical scrutiny.

CHAPTER FOUR

THE SUPERIOR PROPOSALS FROM SUPERCOMPLEX KNOWLEDGE

From Supercomplex Knowledge (SK), we seek to overcome old unresolved obstacles left by previous theories. With this purpose, as we will see throughout the book, we clearly define the object of study -complex systems- and their essential components; we distinguish scales, levels, and differences of complexity for each macrosystem; we propose falsifiable and refutable descriptors and conceptualizations; we describe behaviors through the triad emergence-resistance-tension, without favoring any of them; we develop mathematical and computational models derived from the theory itself; and, above all, we start from the foundation of multiscalar complex constructivism and probabilistic multicausality.

Here lies the presence of an integrative proposal, thoroughly observant and one that has gathered the most brilliant aspects of related theories. From General Systems Theory, we have taken its approach in terms of interrelated systems; from Complex Thought, its philosophical perspective and its emphasis on interconnection and interdependence; from Complexity Sciences, some of its main descriptors and mathematical analysis when addressing emerging patterns[51]; from Theories empha-

[51] The Sciences of Complexity (SC) are criticized for the centrality and exclusivity they assign to the initial states of a system and how this situation can lead (butterfly effect) to drastically different outcomes. The SK critiques this approach as being undemonstrable in many cases, since the formation of patterns is not a universal constant and, moreover, the stochastic complexity postulated by the SK goes beyond the mere search for patterns. The SK emphasizes that patterns are only a momentary illusion within a dynamic intersystem where fluctuations and stochasticity play a central role. By focusing on the search for patterns, SC reduces complexity to something more predictable and linear, when in reality most complex systems do not follow that framework. Equally concerning is the preference of SC for fractal morphology. The SK is not limited to fractal morphology but incorporates other

sizing Self-organization and Evolutionary Complexity, their research regarding adaptation, evolution, and internal organization of systems; from Complex Adaptive Systems Theory, the ability of systems to evolve and structurally adapt to challenges and changes from the outside; and from Network Theory, its conceptualizations regarding nodes and their relationships, along with the sharpness of its approach in highlighting the importance of certain nodes and connections. Naturally, only those perspectives we consider most notable have been mentioned, and to which we owe recognition. From this foundation, we reiterate, we propose that the understanding of complex systems must involve disaggregating the interacting systems and understanding their energy flows, structural morphologies, and temporal connectivity; the overlapping of macrosystems (microparticles, macroscopic, and biological) and the effects of their interactions; the construction of descriptive, predictive, and intervention maps; the rejection of the search for fixed patterns and the need to integrate the characteristics of complex systems into four-dimensional maps and dynamic models that can guide intervention in real systems. Finally, SK continues to be an evolving framework, open to criticism and interdisciplinary collaboration.

To begin unfolding the proposal, it is worth presenting the aspects we consider most important within the theoretical framework itself. Among the most outstanding contributions is the tripartition of the components of complex systems, based on energy flows, structural morphology, and temporal connectivity,

complex structures, such as spirals, toroids, hexagonal systems, among others. These structures, which in many cases appear combined, allow for modeling a greater variety of systems and explain complexity in a more comprehensive way.

which allow for the description and modeling of any system from a supercomplex perspective.

For SK, the concepts of energy, space, and time are not static entities, but elements in constant transformation. This dynamic is reflected in the emergences that occur within energy flows, structural morphologies, and temporal connectivities. These emergences may originate in any of these components in isolation, in pairs, or even in all three simultaneously, generating new states or configurations within the system.

Another key aspect is the classification of reality into macrosystems, encompassing three fundamental levels of complexity: the microparticles, the macroscopic, and the biological. These levels interact through a dynamic bidirectional triple overlap, giving rise to an interconnected and evolving universe.

Additionally, it is maintained that the description of complexity must include intra-, inter-, and intersystem perspectives, as well as consider the brain's capacity to understand itself and its relationship with reality. However, it is worth clarifying that we believe complexity cannot be defined in a fixed or exhaustive way since it is a relational and situational concept. Ultimately, for SK, complexity is the state of a system that ranges from temporary stability through dynamic tension of its energy flows, structural morphology, and temporal connectivity, passing through fluctuations and reorganizations of its internal components, to the highest emergence, which consists of transforming itself (through fluctuations and internal reorganizations, coupling, fracture and reconfiguration, fusion, bifurcation, subsumption, phagocytosis, reciprocal absorption, internal catalysis, creative collapse) into a new system.

Supercomplexity, on the other hand, is understood as a construct where the bidirectional triple overlap between macrosystems (microparticles, macroscopic, and biological), each with specific descriptors, converges with the intervention categories of the human researcher and developer intertwined with instrumental technoengineering techniques of observation and description.

At a methodological level, mathematical modeling and procedural steps for intervention in systems allow for a more detailed and applicable understanding of complexity. Additionally, the development of specialized software facilitates the modeling, mapping, and construction of algorithms to intervene and modify complex systems efficiently. Both aspects are the result of extrapolating theoretical categories into praxis, achieving a circular theory with continuous feedback. Thus, SK is not limited to describing or analyzing complexity but also proposes specific methods of intervention, such as the construction of dynamic algorithms with permanent supervision.

Finally, SK introduces the concept of educomplexity and superlearning, where education is reconfigured to address the challenges of learning in a supercomplex world, forming human beings who are more resilient and better prepared to interact with complexity.

In recent years, we have had the opportunity to engage in dialogue with various actors working with Complexity Theories, and without exception, they have understood and encouraged our effort to propose a unifying yet surpassing framework of the most conservative and traditional approaches. Both in our proposal and in the feedback received, several benefits were highlighted:

- A greater global understanding of the paradigm that incorporates the best, the most widely agreed upon, and the strategies used in successful interventions within the diverse perspectives and approaches of the complexity field. This would allow for a more comprehensive understanding of complex systems in nature, society, and other domains.

- Synergy would be ensured through the circular combination of different methodological tools such as description, modeling, and the use of algorithms.
- A global invitation to develop taxonomies and inclusive maps of all complex systems and the various disciplines involved. This would enable a more effective approach to challenging problems and lead to more significant advances in the understanding and resolution of complex issues.
- Basic agreements could facilitate the application of complexity concepts and principles across a variety of fields, from biology and physics to economics and sociology. This, by having a common language and a unified theoretical framework, would have the potential to drive innovations in various disciplines and foster transdisciplinary collaboration among actors and institutions connected to complexity.
- This proposal for advancement does not aim to discourage the extensive activity that has been taking place in different areas of scientific and technological work, nor to undermine the richness of Complexity Theories in terms of the diversity of participating approaches and schools of thought.
- Global challenges and more intricate problems could be addressed, benefiting both science and society in general.

We seek, in fact, to build a synthesis and a surpassing of different approaches within Complexity Theories, intertwining the most relevant and dynamic concepts along with the incorporation and articulation of new principles, aspiring to a broader and more enriching perspective for understanding complex systems. This convergence could represent an evolution and advancement that integrates the best of various approaches to address the challenges of complexity.

Our proposal initially involved a thorough review of the proposed concepts and the identification of key principles shared by the different Complexity Theories, promoting an interdisciplinary model that enables collaboration and dialogue, which could foster the integration of complementary ideas and developments. Another of our objectives was to consider a hierarchy of complexity with different levels of organization, including the microparticle, macroscopic, and biological macrosystems, interacting and influencing each other. Finally, we aimed to provide a flexible theoretical framework capable of accommodating and encompassing diverse approaches without restricting the richness of Complexity Theories. This would allow different theories and models to coexist under a general conceptual framework.

We are aware that there have already been attempts to achieve the unification and advancement of Complexity Theories. Where, then, does our strength and originality lie? First and foremost, we have been faithful builders of knowledge and action, articulating and combining, with the greatest logic and intellectual honesty possible, what the existing theories already offer of value, along with new enriching contributions.

Here we highlight some aspects that we consider give value and competitiveness to SK:

1. A philo-techno-scientific body of knowledge is articulated, associated with a cognitive stance (complex multiscalar constructivism).[52]

[52] A "knowledge" is something that goes beyond a science or a mode of thought because it integrates multiple disciplines and perspectives, addressing complex problems in a comprehensive and transdisciplinary way. It encompasses not only theoretical understanding but also practical application and philosophical reflection on its meaning and consequences. Furthermore, it is dynamic and adaptable, capable of evolving with new

2. An object of study is defined that is neither reductive nor overextended.

3. The central components of complex systems and their interrelation are identified: energy flows, structural morphologies, and temporal connectivity.

4. Different macrosystems and systems are postulated, each with its own type of complexity.

5. A perspective on the three macrosystems is proposed, framed as a dynamic bidirectional overlap.

6. Supercomplexity is conceived as the result of the complexity of macrosystems, their overlap, and the understanding of the human brain itself and its intervention in reality. In other words, supercomplexity incorporates new levels (into complexity) through active modification and cognitive and technological reconfiguration by the observer-developer, enabling the visualization, and eventual modification, of new events, new combinations, and new circularities in the universe, life, and the human brain.

7. Complex multiscalar constructivism is the epistemological foundation, and probabilistic multicausality is the starting point of a new conception of science (descriptive, prescriptive, and developmental).

8. It is interdisciplinarily linked with classical sciences and very diverse theoretical frameworks: neurosciences, data science, field theory, complex network theory, rhizomatic theory, grounded theory, among others.

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discoveries, and always attentive to the ethical dimensions and values involved in its application. For these reasons, SK offers a broader and deeper framework than Complexity Sciences or Complex Thought, providing a more integrative and effective way to understand and intervene in the supercomplex reality we face.

9. Novel descriptors of complex systems are selected, allowing the approach to emergent, resistant, and tension phenomena, both at the intrasystem and intersystem and entresystem levels.
10. Mathematical, computational, and conceptual descriptions and modelings are integrated.
11. Learning in biological systems is theorized from three fundamental descriptions: computation, mapping, and timekeeping.
12. Possible methodological strategies are presented for applying SK to real problems, based on the construction of procedural steps intrinsic to the theoretical framework, with special emphasis on the transformation and enhancement of institutions and companies.[53]
13. A software tool is developed for modeling, mapping, and algorithm construction. Additionally, the modeling of complex systems is multidimensional with the aim of building maps and algorithms for description, prediction, and intervention.
14. It leads to the need for an educomplexity and superlearning.
15. It concludes with a revolutionary proposal for the construction of scientific knowledge, enabling the compatibility of quantum mechanics and general relativity, and potentially becoming a theory of everything.

The SK aspires to constitute itself as an integrative and, at the same time, surpassing paradigm of the traditional perspectives on complexity. In this paradigmatic endeavor, it raises the most important banners of classical mechanics, quantum mechanics, fluid mechanics, thermodynamics, relativity, network theory, systems theory, information theory, game theory, self-organization theory, among others, resorting

[53] In chapter ten, we provide a brief presentation of the transformation and empowerment program for institutions and companies, as well as the software we are developing.

to technology to promote a new conception of science. In this sense, classical science, particularly classical physics, has historically focused on the study of spatial changes rather than energetic changes. Classical physics was mainly developed to describe and understand the motion of objects in space and time, and the fundamental laws of Newtonian mechanics, for example, focus on the movement and interactions of objects in terms of positions, velocities, and accelerations. However, over time, as scientific understanding has evolved and deepened, the importance of considering energy as a fundamental property of matter and the universe has been recognized. This led to the development of thermodynamics, fluid mechanics, and other branches of physics that focus on the energetic aspects of systems. Einstein's theory of relativity and quantum mechanics, which are pillars of modern physics, also incorporate concepts of energy into their theoretical framework. Moreover, thermodynamics, which studies energy changes in systems, has become essential in fields such as chemistry and engineering, as well as in the understanding of natural and technological processes.

On the other hand, the evolution of science toward new forms of understanding and approaches is manifested in the interweaving and interconnection between scientific disciplines. The traditional boundaries between fields of study often become blurred and permeable due to the inherent interconnectedness of knowledge. This, while potentially generating challenges in defining disciplinary limits, also fosters fruitful collaborations and innovative discoveries.

Transdisciplinarity is a key concept that emerges in this context. It emphasizes that certain contemporary problems cannot be effectively solved from a single discipline but require the collaboration and integration of knowledge from multiple fields. This perspective aligns with the position of the SK, which highlights the interconnection of systems and the need for integrated theoretical frameworks to understand complex phenomena. A paradigm implies understanding a system as a whole, recognizing the interdependence and relationships among its components, which contrasts with a fragmented and isolated analysis of individual parts.

Finally, we want to point out that the traditional concepts of "medium" or "environment," "initial conditions," and phenomena such as the "butterfly effect," as well as the search for patterns, attractors, and the use of the fractal as a central morphology, are considered by the SK as reductionist and insufficient. The SK rejects the notion of an external "environment," "medium," or "surrounding" that influences complex systems in an isolated manner. Instead, every system is seen as part of an interconnected network -interwoven and overlapping, without "voids"- where there is no independent external environment, but a constant and dynamic interrelation among systems.

The SK considers that the search for fixed patterns and attractors limits our understanding of the true nature of complex systems. Instead of focusing on immutable or deterministic patterns, the SK proposes that systems should be analyzed through dynamic maps, allowing greater flexibility and adaptability. This approach avoids the constraints of repetitive structures and fosters a more innovative analysis.[54]

[54] Much of complexity theory, including Chaos Theory and certain approaches within complex networks, has fallen into a movement of self-deception by attempting to reduce genuine complexity to deterministic and controllable models. Although non-linearity and unpredictability are acknowledged at the discursive level, there remains a persistent desire for epistemic and technical domination over complex systems, which contradicts the very nature of complexity itself. The SK proposes to overcome this conceptual trap through a combinatorial, relational, and open attitude that renounces the illusion of total control.

Likewise, describing complexity in terms of "order" or "disorder" is reductive. According to the SK, this binary hinders transformative action: associating "disorder" with chaos or failure generates aversion to exploring new combinations, while associating "order" with success or stability fosters an obsession with control that can stifle both adaptability and innovation. Instead of perpetuating this dichotomy, the SK proposes an integrative and combinatorial approach. What is crucial is neither to control nor classify systems, but to manage the relationships and transitions within them. From this perspective, complexity is understood as a dynamic network of interactions, where "order" and "disorder" coexist and overlap.

On the other hand, the use of the fractal as a central descriptor in many complex systems is considered by the SK as a useful but insufficient tool. Although fractals can represent certain characteristics of systems, they do not encompass the diversity or richness of possible structural morphologies. The SK broadens this view by proposing a more diverse taxonomy that includes hexagons, tori, spirals, and other forms, offering a more complete and realistic description of complex systems. This approach avoids excessive simplification that could limit our understanding of richer phenomena.

In summary, the SK expands and overcomes the limitations of traditional metaphors and concepts, proposing a dynamic, interconnected, and diverse framework to describe both the evolution and the structure of complex systems.[55]

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[55] Moreover, the SK has several points of contact with concepts such as Boolean networks, fitness landscapes, and complex adaptive systems, as they share approaches concerning interaction, adaptability, and emergence in dynamic systems. Boolean networks represent complex systems where nodes have discrete states (such as on/off), which aligns with the SK's approach to nodes possessing energetic, spatial, and temporal characteristics. In the SK, the configuration and relevance of nodes (hot, warm, cold) resonate with the binary logic of Boolean networks. Kauffman's concept of "fitness landscapes" describes how a system seeks to optimize its "state" within a multidimensional space of possible configurations. The

THE SK IN THE MAP OF COMPLEXITY THEORIES

Brian Castellani and Lasse Gerrits have created a "Map of the Complexity Sciences" that provides a broad and interdisciplinary overview of the field. This map encompasses the historical development, key thinkers, and connections between various subfields, such as systems science, computational modeling, and network theory. It highlights the evolution of complexity science and shows how different theoretical perspectives intertwine.[56]

The SK aligns with several of these key areas:

- General complexity and organized complexity.
- Network theories and cognitive sciences.
- Integrative complexity.
- Applied complexity.
- Interdisciplinary methods.
- Hierarchy in complex systems.

This position emphasizes the SK's commitment to integrating theory and practice, situating itself at the intersection of these areas in Castellani and Gerrits' map. Thus, the SK is presented not only as an emerging theoretical framework but also as a unifying paradigm that incorporates and

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SK addresses this idea from the perspective of evolutionary combinatorics and the interaction of energetic, structural, and temporal variables. In the SK, the survival and well-being of a system depend on the quality of the combinations of internal and external factors, resembling how a system navigates a fitness landscape in search of peaks (local or global optima). Complex adaptive systems, as described by Holland, emphasize the capacity of systems to learn, adapt, and evolve. The SK adopts and in part expands on this, highlighting how energy flows and structural morphologies affect these dynamics.

[56] Finding a specific author or school of thought on the map is so complicated that it reminds us of the children's books 'Where's Waldo?'. But that is precisely what the Theories of Complexity are: more than a hundred disjointed approaches competing for the attention of researchers and developers.

reorganizes the core principles of pre-existing approaches within the field of complexity.

PARADIGMATIC OBJECTIVES

As previously noted, the SK aspires to transcend theory and become an applicable and unifying tool, adapting and developing postulates that address complexity in an integral and practical manner. This would allow for overcoming reductionisms with totalizing and dogmatic pretensions, as well as "bias franchises."[57]

Complexity becomes ineffective when it is trivialized or confined within reductionist frameworks. The key to the SK lies in the fact that it is not merely a method or methodology but a profound epistemological revision that redefines the relationship between systems, their interactions, and their levels of organization. A perspective on complexity is undermined when it is regarded solely as a tool in service of classical disciplines, thereby losing its ontological and epistemological value; when it fails to integrate knowledge or physical, chemical, or biological

[57] For many critical scientists, the Theories of Complexity are nothing more than an impressionistic construct: seemingly profound but, according to them, lacking solid content and real impact to transform human and planetary existential issues. We believe that if these theories are not unified, they risk losing relevance and eventually disappearing. There are three scenarios that particularly concern us:

a) The personalism of some creators of specific approaches, who have centered their proposals on a subjective vision of originality and creativity, demanding almost uncritical adherence to their construction, which they consider absolute despite its partial nature.

b) Institutions that adopt any theoretical framework that uses some key concepts of complexity, without distinguishing between those that are truly integrative and those that dilute the theoretical meaning of the discipline.

c) The association with other models that, in the long run, limit and weaken the perspective on complex systems, as occurs, for example, with Chaos Theory. Although this theory introduced significant contributions to the study of nonlinear systems and their sensitivity to initial conditions, it was quickly reinterpreted by many scientists under a logic of seeking new determinisms. It seems as if finding the 'strange attractor' would be enough to domesticate complexity within a definitive model. At its core, a significant part of the scientific community, although working with complexity discourses, is not willing to abandon its traditional position of control over phenomena.

objects, fragmenting its scope instead of addressing interacting systemic wholes; and when it ignores that monocausal approaches lose meaning with the advancement of AI and supercomputers, technologies that allow for dynamic and multivariable mapping and modeling of systems. It is also weakened when reduced to a mere philosophical category without practical impact or to a simple mathematical gradient, thereby losing its power as a transformative paradigm. True complexity, for the SK, must be maintained as an integrative, operative, and combinatorial knowledge, capable of describing, predicting, and intervening in reality without being absorbed by fragmentary approaches.

THE SUPERCOMPLEX KNOWLEDGE IN COLLABORATION WITH THE SCIENCES OF COMPLEXITY AND COMPLEX THINKING

The SK shares affinities with Complex Thinking and the Sciences of Complexity but also introduces key innovations. To visualize both the points of convergence and the differentiating elements of each approach, we present the following comparative table:

Aspect	**Sciences of Complexity (SC)**	**Complex Thinking (CT)**	**Supercomplex Knowledge (SK)**

Object of Study	Complex dynamic systems at different levels (biological, social, physical).	Complex thinking and the integration of knowledge across different disciplines.	Complex and supercomplex systems in interaction (microparticles, macroscopic, and biological), with the intervention of the observer-developer.
Epistemological Approach	Multidisciplinary, but with a foundation in mathematical models, network theory, and adaptive systems.	Holistic approach based on the interconnection of systems, with emphasis on Morin's Complex Thinking.	Ontological-relational-combinatorial approach focused on interaction, energy, and dynamic structures.
Modeling Framework	Mathematical models, computational simulations, and complex networks.	Conceptual modeling based on interactions and transdisciplinary integration.	Four-dimensional mapping based on energy flows (EF), structural morphologies (SM), and temporal connectivity (TC).

Treatment of Variables	Prioritization of key variables, but with difficulty in integrating multiple dimensions.	Describes complexity through multiple dimensions but lacks strong quantitative modeling.	Dynamic integration of all relevant variables, with an evolutionary combinatorial approach.
Prediction and Control	Identification of stable patterns and universal principles, with a focus on optimization and stability.	Seeks to understand emergence and evolution, without control.	Does not seek fixed patterns but rather understands how fluctuations and non-constants generate new configurations.
Scalability of the Model	Works well at specific scales but faces challenges in multiscale integration.	Conceptual scalability but lacks operational tools for system intervention.	Scalable to any system, as it works with emergent and flexible structures.
Role of the Observer	The observer analyzes from outside the system,	The observer is part of the system but with a more	The observer is an active part of the system, modifying it

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	without intervening in its dynamics.	philosophical than practical role.	and being modified in real-time.
Applicability in AI	Increasing use of AI but reliant on traditional statistical models.	Limited applicability, lacking formal models for integration in advanced AI.	Use of combinatorial AI and 4D networks to optimize real-time interventions and enhance system understanding.
Future Potential	Expansion in data sciences and more advanced simulations but without integrating active observer intervention.	Could influence education and epistemology models but with limited impact on practical modeling.	Maximum potential to integrate artificial intelligence, optimize complex systems, and develop a theory of everything.

Areas of Transfer and Problems to Address	Optimization of industrial processes, social network analysis, climate change modeling, computational economics.	Ethics of knowledge, transdisciplinary education, culture and art, critical epistemology.	Advanced AGI, neuroscience, biotechnology, education, business and institutional optimization, cybersecurity, geopolitics, energy, personalized health, space exploration.

CHAPTER FIVE

A BRIEF HISTORY OF ENERGY, SPACE, AND TIME THROUGH THE LENS OF SUPERCOMPLEX KNOWLEDGE

Energy, space, and time are not isolated concepts nor passive components of the universe. Their simultaneous emergence and joint evolution allow us to trace a line from the first quantum fluctuations to the appearance of consciousness and artificial neural networks. Within the framework of Supercomplex Knowledge (SK), these three dimensions form an interdependent fabric whose dynamic interaction is key to understanding the evolution of the cosmos and the emergence of complexity.[58]

Throughout history, the understanding of energy, space, and time has been fundamental to science, philosophy, and technology.[59] Einstein's theory of relativity demonstrated that time and space are not absolute, but relative to the dynamics of energy within a system. This revelation changed our under-standing of

[58] As a kind of prequel in the scientific projection that almost all models, whether intentionally or not, tend to make, we believe that massive inflation could be interpreted as an event resulting from multiversal interactions, in which energy flows, spatial configurations, and temporal dynamics intertwine in a complex and emergent manner. This model, compatible with theories such as cosmic inflation and the inflationary multiverse, proposes that the universe is not an isolated system, but part of a larger macrosystem whose evolution responds to combinatory and stochastic processes. Within this framework, energy functions as an organizing flow, space behaves as a flexible fabric subject to interuniversal tensions, and time emerges as a relational network connecting these processes. This perspective, from the standpoint of SK, offers an expanded and relational interpretation of current cosmological phenomena.

[59] David Bohm proposed the idea of the "implicate order," according to which the universe is not composed of separate elements but is a dynamic totality where space, time, and energy emerge from a deeper underlying structure. For his part, Ilya Prigogine argued that the evolution of the universe is irreducibly indeterministic and that initial quantum fluctuations played a crucial role in the emergence of complex structures, which reinforces the SK perspective on the interconnectivity of energy, space, and time.

the universe, showing that energy, mass, and spacetime are deeply interrelated.[60]

Subsequent advances in complex systems theory further expanded these ideas by highlighting the importance of interactions across different scales and systems. In modern physics, two essential theories for understanding the universe are general relativity and quantum mechanics. General relativity describes how energy and mass curve spacetime at the macroscopic level, while quantum mechanics governs subatomic interactions at the microscopic level. Although these theories operate within separate domains, the SK posits that the interrelation of energy flows at both levels shapes the structural and temporal dynamics of systems.

The SK presents itself as an integrative paradigm, offering a profoundly dynamic, stochastic, and relational view of the universe.[61] Within this framework, energy, space, and time are not separate categories, but are always interrelated. As energy interacts with system structures, it not only shapes space and time but also induces continuous transformations within them. This

[60] Stephen Hawking explained how general relativity transformed our view of space-time by demonstrating that its geometry is modified by the presence of energy and mass, establishing a fundamental connection between these dimensions. Carlo Rovelli argues that time is not an absolute entity, but rather emerges from interactions between quantum systems, in alignment with the SK's view on the multiplicity of temporalities.

[61] The SK aligns with those theories that propose the universe did not emerge from nothing nor from an absolute singularity, but rather from a multiversal cosmic inflation, the result of energetic interactions between pre-existing systems. Models such as Alan Guth and Andrei Linde's eternal inflation, as well as the proposals of Alexander Vilenkin and Max Tegmark on the multiverse, suggest that our universe is part of a broader dynamic of quantum fluctuations. Similarly, Roger Penrose and Neil Turok have proposed cyclical models in which the expansion and contraction of the cosmos are part of a recurring process. Far from being a unique and unrepeatable event, cosmic inflation was a phase transition within a combinatory interplay of energetic flows that reconfigured the structural morphology and temporal connectivity of space-time. The expansion of the universe was not the beginning, but rather the continuation of a supercomplex process in which order and disorder coexist and are constantly recombined, as suggested by the approaches of Ilya Prigogine and Lee Smolin on the evolution of dynamic systems and the emergence of time.

implies that system structures are in constant flux due to energy flows, leading to a non-deterministic evolution.

More concretely, just as in Einstein's relativity, where energy can curve space and alter our perception of time, the SK suggests that these three elements (energy, space, and time) are primarily relational and correlational. However, the SK takes a step further by integrating these concepts into a perspective of complexity and supercomplexity, in which each complex system possesses its own temporal and spatial frameworks, determined both by its internal structure and by its interactions with other systems.

A central aspect of this perspective is that complex systems exhibit stochastic behavior. That is, events occur with apparent randomness but are the result of the interplay between self-unfolding (the autonomous development of a system) and the interactions of a complex system with other systems. This perspective allows us to understand that what seems "random" is actually governed by a set of underlying relationships and dynamics that may follow stochastic patterns. This approach enables a richer and more nuanced representation of complexity, aligning with the idea that apparent randomness is, in fact, a manifestation of complex networks of interactions.

By focusing on stochasticity and system interactions, the SK suggests that events do not follow fixed or predictable patterns, nor are they entirely chaotic; rather, they are the result of evolutionary processes and complex interactions, that is, they are products of a much more open and interconnected dynamic.[62]

[62] In this sense, the SK shares conceptual affinities with various approaches in science and philosophy. Prigogine and Kauffman emphasize the non-deterministic evolution of complex systems, while Morin highlights their recursive interconnection. Barabási and Gell-Mann explore the stochastic dynamics in networks and emergent structures, in alignment with the SK perspective. Bohm and Holland reinforce the idea that what appears to be random

The journey of the universe began with small fluctuations in the quantum vacuum, imbalances that propelled the expansion of the cosmos.[63] For the SK, this primordial energy has been the driving force behind complexity, from subatomic particles to biological ecosystems. Traditionally, energy has been conceived as something linear and mechanical, something that is conserved and transferred. However, the SK understands energy as a continuous, multiscalar, and relational flow (with fluctuations and internal reorganizations, couplings, fractures and reconfigurations, fusions, bifurcations, subsumptions, phagocytoses, reciprocal absorptions, internal catalyzes, creative collapses) that interacts with and modifies the structural morphologies of the systems it traverses. It is not only the fuel of complex systems, but also the agent of change that shapes their internal structure and interactions.[64]

For the SK, through its interrelation with energy flows, both space and time are relative, relational, correlational, and understood through three key characteristics: a) they are singular; b) they are relative; and c) they are multiple and interdependent,

actually follows underlying patterns, aligning with the SK's view of the constant interrelation between energy, space, and time.

[63] The hypothesis that our universe could be affected by overlaps with other multiverses has been explored by scientists such as Laura Mersini-Houghton, Matthew Kleban, and Salvador J. Robles-Pérez. Their research suggests that certain cosmological phenomena, such as the cold spot in the cosmic microwave background, could be the result of interactions between universes. SK, by considering the combinatorics of energy flows between interrelated systems, finds in these hypotheses an epistemological correlate that strengthens the multiversal perspective as a network of supercomplex interactions.

[64] Guth explains how the initial quantum imbalances drove cosmic expansion, in line with the SK's idea of primordial energy as the engine of complexity. Chaisson argues that energy gradients drive evolution from subatomic particles to ecosystems, aligning with the SK's view of energy as a structuring flow. Gell-Mann, in turn, describes how emergent patterns and adaptive processes depend on energy fluctuations, reinforcing the SK perspective on multiscale interactions.

since this "dance" of systems gives rise to all the diversity of the universe and of life.[65]

1. **Singularity:** Each complex system possesses a unique temporal and spatial framework, determined by its structural morphology and its internal dynamics, that is, its identity in terms of its energy combination and management.
2. **Relativity:** Space and time are not fixed entities; rather, they are circularly influenced by the energetic interactions between systems, generating variations depending on these interactions.
3. **Multiplicity and interdependence:** The interaction between systems generates a network of interrelated spaces and times, which overlap and coexist, giving rise to the diversity of the universe and of life.

From this perspective, space is singular, relative, and multiple, as each complex system has its own space shaped by its structural morphology; moreover, different spaces emerge from the interaction between various complex systems.[66]

Time is also relative and specific to each system and, moreover, is subject to the contact between systems and their evolution. This perspective suggests that each system creates and defines its own spatial and temporal framework through its internal structures and its interactions with other systems.[67]

[65] Carlo Rovelli argues that time is not an absolute entity, but an emergent construct that depends on interactions between systems. His concept of relational time posits that there is no universal temporal flow, but rather multiple temporalities that vary according to the structure and dynamics of each system, in harmony with the SK's view on the singularity and relativity of time.
[66] This paradigm contrasts with the traditional notion of "vacuum" in physics, which has often been considered as an empty space devoid of matter. However, in modern theories such as quantum mechanics and quantum field theory, the "vacuum" is not truly empty, but rather filled with quantum fluctuations and fields existing in a fundamental state.
[67] Minkowski formulated the notion of space-time as a unified entity, where spatial and temporal dimensions are interconnected and dependent on the dynamics of systems.

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Instead of a single, uniform space, there exist multiple spaces generated by the structural characteristics of each complex system and by those emerging from active interaction with other systems. This means that the way in which a system expands, interacts, or even exists depends intrinsically on its structural form and configuration, distinguishing it significantly from other systems; on the result of contact with those other systems; and on the presence of a third party who performs that description.[68] Put more simply, what we assert is that some interactions expand structural morphologies (space), while others constrain them. Likewise, some interactions accelerate processes, while others slow them down (time).

The conception of time in the SK is strongly interconnected with the dynamic, stochastic, and circular flow between systems, which leads to a specific temporal connectivity for each complex system. This implies a time that is not homogeneous, but instead varies according to the interactions and structural morphologies, aligning more closely with a notion of internal temporality within systems.

In line with systems theory, network theory, or cybernetics, there would be three spatial dimensions: first, the space of the structural morphology of the system; second, a dynamic space generated by active and networked interaction with other

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Lefebvre argues that space is not a passive container, but an active product of physical and social interactions, reinforcing the SK's view on the generation of multiple spaces arising from systemic interactions.

[68] For example, circadian rhythms in organisms adjust according to daylight, temperature, and other factors, demonstrating that "biological time" varies and adapts based on both the internal conditions of the system and those arising from the systems with which it interacts. Similarly, studies on how communities form and operate on social media platforms illustrate how the "social space" of a community is shaped by interactions among its members, as well as by the norms and technologies that mediate those interactions. This can also be observed in cases such as neural networks, where information processing time and the spatial configuration of neuronal connections depend on the network of contacts and their activity.

systems in contact; and third, a perceptual space determined by the relative parameters of the human observer-developer.[69]

1. **Structural space:** This is the space that arises from the internal morphology of a system. It is defined by the arrangement and structure of the system's components.
2. **Dynamic space:** This is the space that emerges from the interaction between complex systems. Here, the flow of energy and interrelations generate new dynamic spaces that evolve over time.
3. **Perceptual space:** This space is influenced by the human observer-developer. The perception of space is mediated by cognitive capacity and the available observational tools, introducing a subjective dimension to the description of systems.

This trifurcation allows us to address both structural objectivity and perceptual subjectivity in our analysis, offering a deeper understanding of how systems operate and evolve.

In this perspective, space and time are not homogeneous concepts. Each system creates and defines its own spatial and temporal framework through its internal structures and its interactions with other systems. Instead of a universal space and time, there exist multiple spaces and times defined by the singularity of each complex system and its relationships with

[69] The third space and time acknowledge the inevitable influence the observer has on the system being studied. From the perspective of quantum physics, it is well known that the act of observation can alter the state of what is observed. In the context of complex systems, the observer's perception, expectations, and conceptual tools can define how the system's spaces and times are perceived and measured. Recognizing a third space and time invites reflection on research methodologies and scientific practices. It promotes a more reflexive and critical approach to how science is conducted, especially in the study of complex systems, where the interaction between the observer and the system can be a crucial factor. In this regard, Norbert Wiener argues that systems not only interact with their environment, but are also influenced by the observer who describes and regulates them. His cybernetic approach reinforces the SK's view of perceptual space as a construction shaped by the parameters of the human observer-developer.

other systems. That is, the concept of time, like space, is not absolute, but varies depending on the specific nature of each system and its dynamic interactions.[70] This implies that temporal connectivity, that is, the "rhythm" or "speed" of processes, can differ significantly between systems, depending on how and with whom they interact.[71] Therefore, temporality is an emergent and dynamic phenomenon, similar to how it is conceptualized in certain interpretations of quantum mechanics and in studies of adaptive complex systems.[72]

For the SK, as we have already stated, complex systems exhibit a dynamic coexistence between stabilizing functions, synchronous coemergences, and sequential asymmetric fluctuations. Stabilizing functions ensure the functional organization of the system by synchronizing energy flows and optimizing its structure in the present. In turn, synchronous convergences organize components and functions in simultaneous interaction, achieving cohesive and stable morphological configurations. On the other hand, sequential asymmetric fluctuations introduce progressive imbalances, reorganizing structural morphologies

[70] This can influence, for example, how we approach ecosystem conservation, the design of personalized medical treatments based on systems biology, and genetic engineering, where contact systems and individual variability are crucial.

[71] This idea surpasses the Newtonian notion of space and time as absolute and universal. Moreover, since each system not only operates within its own framework but also co-creates new frameworks through its interactions, it aligns in parallel with concepts in physics such as Einstein's general theory of relativity, where gravity is seen as the curvature of space-time caused by masses. Prigogine worked on far-from-equilibrium thermodynamics, where he emphasized the importance of open systems and how they can exhibit complex temporal behavior.

[72] Wouldn't this conception come into conflict with the so-called constants proposed by classical science? There are several objections to consider: a) Constants are provisional, since although they are considered universal, they could vary under extreme conditions, on uncommon scales, or in systems that have not yet been studied in depth (such as black holes or extreme quantum scales); b) certain constants could, in some sense, be the result of specific conditions, as in quantum mechanics where observation affects the state of the system being observed; c) some constants are proposed for certain macrosystems, but it is not known whether in other macrosystems they will retain the mathematical parameter corresponding to the original causal relationship.

and reconfiguring temporal connectivities, which gives rise to innovations and evolutionary adaptations. It is through this dynamic combinatory process, in which energy flows are efficiently managed, structures are constantly reorganized, and temporalities are inter-woven, that functional stability and adaptive change are balanced, thus ensuring the evolution and survival of the system.[73]

For all these reasons, the plurality and diversity of the systems that surround us are grounded in how energy flows, through their interaction with different structural morphologies over time, intertwine, overlap, and mutually influence one another, generating an incredible variety of systems with their own particularities and internal processes. These systems operate in an interrelated manner, increasing the degree of complexity in the world and in life, and, consequently, the complexity of the tools needed to adequately address complex phenomena. From this perspective, the apparent immobility or linearity of certain systems, and the intention to work on them in isolation, gives way to the reality of their interrelation effects.

From quantum structure to artificial neural networks, complexity intensifies as these three elements interact in increasingly intricate ways. In biology, for example, the energetic flow of metabolism is intimately connected to the spatial structure of organisms and to the temporal connectivity that enables evolution and adaptation. In technology, artificial neural networks symbolically replicate these principles by processing

[73] Maturana and Varela developed the concept of autopoiesis, which describes how living systems maintain their identity through processes of self-organization and functional stability, aligning with the SK's view on stabilizing functions and energy synchronization. Eigen, for his part, introduced the theory of hypercycles, where evolution depends on networks of interactions that synchronize functions and reorganize structures, in harmony with the SK's view on synchronous co-emergence and adaptive fluctuations.

large amounts of data and learning through feedback from new inputs.

A fundamental milestone in the history of complexity is the emergence of consciousness, understood in supercomplex terms as the highest manifestation of the interconnection between energy, space, and time. Consciousness is not only an emergent property of complex biological systems, but also a catalyst that allows systems to transform both their own structures and those of the systems with which they interact.[74]

The SK's complete rejection of determinism positions it as a unique and radically different paradigm. This vision emphasizes indeterminacy, creativity, and emergence as fundamental principles for describing, modeling, and modifying complex systems.

[74] Damasio argues that consciousness arises from the interaction between biological structures and energy flows, in alignment with the SK's view of its emergent nature. Koch develops the Integrated Information Theory (IIT), according to which consciousness is a degree of interconnection within a system, aligning with the SK's idea of the interdependence between energy, space, and time. Chalmers distinguishes consciousness as a physical phenomenon from the "hard problem" of subjectivity, reinforcing the SK's perspective on consciousness as an advanced manifestation of complexity. Penrose suggests that consciousness may be linked to fundamental quantum processes, complementing the SK's view of its role in the structural transformation of systems. Varela, Thompson, and Rosch propose that consciousness is a dynamic and situated phenomenon, emerging from the interaction between organisms and their environment, in tune with the SK's view of its capacity to modify systems of exchange.

CHAPTER SIX

THE MACROSYSTEMS

In the previous chapter, we stated that Supercomplex Knowledge (SK) is devoted to a universal dynamic in which energy flows continuously and variably interact with each other, with different structural morphologies, and with time, through temporal connectivity (the activation and deactivation of behaviors and functions). This generates the construction of a wide range of systems with different characteristics, each possessing internal processes that may self-organize stochastically. These systems not only operate in isolation but also affect and are affected by other systems, engaging in feedback loops and eventually changing, adapting, and evolving in order to remain relevant or viable over time. This occurs through morphological changes in response to challenges or shifting internal needs, or by opening up to the demands of the systems with which they actively interact.

One of the historical limitations of many Theories of Complexity has been the tendency to focus almost exclusively on macroscopic macrosystems (galaxies, planets, ecosystems, etc.), where the dynamics between energy, space, and time are slower and more predictable compared to microparticle or biological systems. In fact, quantum dynamics have a significant impact on larger systems, and ignoring this scale means excluding an essential part of complexity. Quantum fluctuations, the principles of uncertainty, and quantum superpositions introduce stochastic and nonlinear behaviors that must be considered in any theory of complexity. Meanwhile, the biological macrosystem presents a unique complexity due to the variability of its systems and the constant interaction between intrasystemic and intersystemic elements. Here, interactions are much more dynamic, and temporal connectivity plays a crucial role in evolution, adaptation, and emergent behavior.

This interweaving of macrosystems and systems, with their respective behaviors and functions, has generated a situation of processes that have exploded in their complexity, processes that can only be described through dynamic methodologies.

The taxonomy we propose is provisional, and we believe this does not diminish its value. On the contrary, it only highlights the ongoing dynamic renewal of systems and observational perspectives. It is a tentative proposal, open to changes, additions, and reclassifications.[75]

We consider three general macrosystems, each with a type of complexity of its own:

Microparticle Macrosystem	Quantum Complexity
Macroscopic Macrosystem	Macrocomplexity
Biological Macrosystem	Biocomplexity

This systematization, this proposed taxonomy, offers a useful framework for thinking about complexity across different scales and contexts. It provides human observers with an approach to understand and study the vast array of behaviors and functions within our universe. However, it is important to remember that these categories are not rigid; there are zones of overlap, superposition, and transition among them, where boundaries can be blurred and phenomena may be influenced by multiple levels of complexity.

[75] In fact, this taxonomy is operative and functional with the aim of illustrating the different levels of complexity.

These entanglements demonstrate that nature is an interconnected complex system. Studying one level of complexity often requires understanding and tools from another level, and it is precisely this interdisciplinarity and transdisciplinarity that can lead to deeper insights and discoveries.[76]

1. MICROPARTICLE MACROSYSTEM. QUANTICOMPLEXITY

From an evolutionary standpoint, this universe began 13.8 billion years ago with microscopic quantum fluctuations[77] which, as the cosmos expanded, gave rise to inhomogeneities, irregular and discontinuous structures that originated galaxies and all macroscopic systems. These structures, composed of blocks of matter and energy with specific levels of angular momentum, established the foundation of the complexity observable in the current universe.

The microparticle macrosystem encompasses the smallest scale, the subatomic and atomic level, where quantum mechanics governs the description of interactions and behaviors. Its origin traces back to the earliest moments of the universe, during processes such as baryogenesis and primordial nucleosynthesis.

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[76] Both Peirce's abductive reasoning and the rhizomatic thinking of Guattari and Deleuze can be linked to the three macrosystems proposed by the SK, although their relevance and applicability may vary depending on the level of analysis and the specific nature of the system under study. Abduction is especially useful in the generation of hypotheses and theories at all levels, while rhizomatic thinking is particularly suited to describing and understanding the interconnections and relationships within macroscopic and biological complex systems.

[77] Cosmic inflation had a significant impact on the energy flows, structural morphology, and temporal connectivity of the universe. Before cosmic inflation, energy was extremely concentrated in a very small region of space. The energy flows were chaotic due to the high density and temperature. No defined structures existed; the universe was in a primordial state of quark-gluon plasma. Events and interactions occurred at an extremely rapid pace due to the high energies. After cosmic inflation, the universe's energy dissipated quickly, significantly reducing the energy density and beginning to flow in a more directed manner, allowing for the formation of larger and more complex structures.

In this period, elementary particles like quarks, leptons, and gluons combined to form protons, neutrons, and eventually light nuclei. This early organizational process introduced diversity and complexity, laying the structural groundwork of the universe.

The interactions between particles not only gave rise to matter but also generated emergent phenomena that cannot be explained solely from the behavior of individual particles. Examples include the Higgs field, which grants mass to particles, and multiscale quantum interactions, which produce nonlinear and highly interconnected behaviors. These quantum phenomena highlight how complexity can emerge from seemingly simple dynamics when observed within broad and deeply interrelated systems.

Quantum physics reveals that a microparticle is not "tied" to a single location or state as we typically imagine in the macroscopic world. Instead, it behaves like a network in which each particle (like a bee within its swarm) is connected to and influenced by others, in an almost "choreographed" fashion. This network of connections, though counterintuitive, has been experimentally verified, revealing a level of complexity and organization in nature that surpasses what we can perceive with our senses and everyday intuition.

This network behavior and the idea of the particle-as-swarm compel us to view space and energy flows not as defined trajectories but as dynamic and interdependent interactions. Quantum theory reminds us that the universe is not merely composed of isolated entities, but is, at its core, a vast and subtle web of relationships.

Furthermore, energy behaviors are radically different due to the quantum nature of particles and the laws that govern them.

In these systems, instead of continuous movements as in macroscopic ones, we find phenomena such as:

1. **Quantum Superposition (Multi-ubiquity):** Particles can exist in multiple states simultaneously until a measurement is made.
2. **Quantum Tunneling:** Particles can cross energy barriers that, from a macroscopic perspective, would appear insurmountable.
3. **Quantum Fluctuations:** Due to the probabilistic nature of quantum mechanics, particles in a vacuum can undergo spontaneous energy fluctuations.
4. **Quantum Entanglement:** Two or more particles can instantaneously correlate their states, regardless of the distance separating them, representing a form of interaction that does not involve classical transmission.
5. **Quantum Interference:** By behaving both as waves and particles, quantum systems can exhibit interference patterns that are invisible at the macroscopic scale but are crucial at the level of microparticles.

At the quantum level, it is difficult to distinguish between the energetic and the structural, because particles do not behave like the macroscopic objects we are used to. Some key reasons for this difficulty include:

1. **Wave-particle duality:** Quantum entities such as electrons or photons can behave both as particles (defined structures in space) and as waves (manifestations of energy). This duality makes it difficult to strictly separate "energy" from "structure," as both behaviors are intrinsically linked.

2. **Quantum superposition or multi-ubiquity[78]:** A particle can exist in multiple states or positions simultaneously, blurring the clear distinction between a defined structure and its associated energy levels. Only when a property, such as position or energy state, is measured does the particle adopt a concrete value.
3. **Uncertainty principle:** It states that it is not possible to simultaneously know with absolute precision two complementary properties of a particle, such as its position (structure) and momentum (energy in motion). This means that defining a structure precisely affects the understanding of energy and vice versa.
4. **Quantum entanglement:** Entangled particles do not have a localizable structure or an individual energy state that can be described independently. The energy and structure of each particle depend on its relationship with the other entangled particle, further complicating the separation between these concepts.
5. **Wave function:** It describes the state of a system, including both its spatial distribution (structure) and its energy configuration. This function cannot be directly observed, only its probabilistic effects upon measurement.

In summary, at the quantum level, the classical categories of "structure" and "energy" become entangled and, in many cases, indistinguishable, since energy can manifest itself structurally and structures can be defined in terms of energetic probabilities. Quantum physics challenges the intuitive notions of cause and effect, continuity, and localization that our brain uses to navigate the macroscopic world.

[78] To state that a particle is in "superposition" is equivalent to stating that it is in relational multi-ubiquity, meaning that its location and state depend on its temporal connectivity (TC) and structural morphology (SM) within the system.

The microparticle macrosystem, due to its subatomic and quantum nature, is considered the most complex of all systems. The presence of an observing subject adds even more complexity to the system, due to Heisenberg's uncertainty principle and the observer effect in quantum mechanics. This means that the mere observation of a quantum phenomenon can alter its state, making measurement and prediction extremely challenging.

Complexity in the microparticle macrosystem manifests as the result of a combination of interactions, mainly through quantum and electromagnetic interactions. These interactions, which include quantum entanglement, superposition, and electromagnetic forces between subatomic particles, generate structural configurations in constant change. In the context of SK, these interactions are not merely linear or deterministic, but reflect how energy flows can organize into new structures through complex and stochastic dynamics. This dynamic is not fully predictable due to the probabilistic nature of quantum systems and the multiple ways in which these complex systems can interact with one another.

Complex behaviors in quantum physics demonstrate that: a) the elements of a quantum system are intrinsically inter-connected and cannot be understood in isolation; b) these systems do not follow linear or predictable trajectories, which challenges deterministic models; c) absolute prediction and control are unfeasible, making it necessary to resort to probabilities and consider emergent scenarios; d) the existence of phenomena such as superposition requires multidimensional models for proper understanding, which highlights the relevance of advanced paradigms.

The SK proposes that complexity in this macrosystem should not be understood in deterministic terms, but rather as the result of a network of interdependencies between systems at different levels of organization (intrasystemic and inter-systemic). This position is key to understanding the unpredictability and stochasticity that characterize quantum systems and how these properties influence the generation of new structural configurations.

In microparticle systems, such as those found in condensed matter physics, chemistry, and molecular biology, the interaction between energy flows, structural morphology (space), and temporal connectivity strategies is fundamental to understanding the dynamics and properties of the system. In these systems, energy flows can manifest in several forms, such as thermal energy, chemical energy in reactions, electromagnetic energy in charge interactions, and mechanical energy in movements and deformations. These energy flows can alter electronic states, molecular conformations, and interactions among microparticles, which, in turn, affect the structure and function of the system. Structural morphology in microparticle systems refers to the spatial arrangement and organization of particles, which can range from highly ordered crystalline structures to more disordered amorphous or liquid configurations. Morphology influences how microparticles interact and how energy flows are distributed and dissipated within the system. The transport, optical, magnetic, and electronic properties of the system are deeply influenced by its spatial structure. In these systems, "on-and-off strategies" may relate to phase transitions, conformational changes, chemical reactions that are activated or inhibited, and the manipulation of quantum states, among other possibilities. These changes may be induced or modulated by energy flows and depend on the structure of the system.

2. MACROSCOPIC MACROSYSTEM AND MACROCOMPLEXITY

The macroscopic macrosystem encompasses the scale ranging from atoms and molecules to stars, galaxies, and the entire universe. At this scale, the laws of classical physics (such as Newtonian mechanics or thermodynamics) are generally applicable. However, as we move toward larger systems, such as galaxies or galaxy clusters, Einstein's general theory of relativity becomes increasingly relevant.

In astronomy, phenomena such as galaxy formation, supernovae, black holes, and the dynamics of galaxy clusters involve extremely complex interactions of matter and energy on gigantic scales. These events not only affect the structure of the universe but also influence the formation of chemical elements and the evolution of stars and planets.

The dynamics of stars are an excellent example of an evolving complex system. Stars maintain their structure thanks to a dynamic equilibrium between the force of gravity, which tends to collapse them, and the internal pressure generated by nuclear fusion, which causes expansion. This balance is not static; it is subject to changes and asymmetries that influence the star's evolution over its lifetime. The tension within stars is similar to how complex systems function in general. These systems are in a continuous state of change due to the various forces and factors that interact within them. Asymmetries, fluctuations, noise, and feedback within the system contribute to its evolution, adaptability, and capacity to generate emergent behaviors.

In the context of SK, this dynamic can be understood as a flow of energy and matter, where multiscale interactions and emergent behaviors are key to understanding the structure and evolution of the system. For example, the periodic table does not deny the existence of complexity; rather, it is a partial representation of a universe that combines order and disorder, regularity and rupture, stability and instability. From the SK perspective, the periodic table is the entry point to complexity, not its negation, and in this sense, it recognizes these local orders but focuses on what occurs when these elements interact with energy, space, and time, forming highly complex living, social, or physical systems.

In the physics of complex systems, phenomena such as meteorology, fluid dynamics, and other systems where multiple variables interact in a nonlinear manner are also studied.

Inorganic chemistry also presents high levels of complexity in macroscopic systems. Although we often associate molecular complexity with organic chemistry due to large molecules and biological structures, inorganic chemistry studies a wide variety of compounds and materials that can be equally complex. Reactions in chemical compounds often exhibit emergence due to the interaction among their constituent elements, and the properties of the resulting compound are often different from the properties of the individual elements. For example, water is a substance with emergent properties that cannot be directly deduced from the properties of hydrogen or oxygen alone.

Some examples of complexity in inorganic chemistry include crystalline and mineral structures that may involve extensive three-dimensional networks with intricate bonding patterns. In addition, transition metals can form complexes with various ligands, creating structures with varied geometries and unique electronic properties.

In the macroscopic macrosystem, complexity emerges from the interaction of classical physical forces, such as gravitation and electromagnetism, which govern the motion and behavior of objects and structures. The laws of classical physics and general relativity predominate at this scale, providing a predictive framework for understanding the evolution of stellar, planetary, and molecular systems. However, complexity arises when we consider the interaction of a large number of particles or bodies, which can lead to nonlinear behaviors and phenomena such as turbulence in atmospheric fluid dynamics or the formation of large-scale galactic structures.

Descriptors of macroscopic system behaviors are the most intuitive and perhaps those that have been most extensively described by physics due to their historical relevance for human observers and the development of observational instruments.[79]

In the macroscopic macrosystem, energy flows include gravitational energy, kinetic energy, thermal energy, and electromagnetic energy that govern the behavior of physical objects. Here, energy transfer is more predictable and follows the laws of classical physics, such as heat exchange, planetary motion, or gravitational attraction.

Structural morphology is tangible and visible, with objects having defined shapes (planets, galaxies, mountains), and these shapes determine how energy flows are distributed and channeled. The distribution of mass and the geometry of bodies directly affect energetic behavior, such as the distribution of gravity in a planetary system or the forces of attraction and repulsion between objects.

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[79] It is important to clarify that SK does not disregard the laws of thermodynamics. However, it acknowledges that these laws were not conceived to describe such emergent and complex combinations as those proposed by the SK, where multiple scales and variables interact under the dynamics of energy flows, morphology, and connectivity.

Temporal connectivity is linear and follows a flow of cause and effect, based on relativity and Newton's laws. Events and interactions follow a predictable temporal sequence. Time is perceived as a continuous dimension, and changes in the system occur in a logical and sequential manner.

3. BIOLOGICAL MACROSYSTEM AND BIOCOMPLEXITY

The biological macrosystem encompasses all forms of life, from microorganisms to multicellular organisms such as human beings. Life in the universe is a network of organizational levels that are progressively constructed, from the simplest components to highly complex systems. This journey toward complexity begins with atoms and molecules, develops into cellular structures, and culminates in the biosphere, the interconnected web of all ecosystems on the planet.

Within the framework of SK, living systems operate through three interdependent dynamics: functions linked to identity and temporal stability, synchronous co-emergent operations, and evolutionary behaviors that arise sequentially and in escalation. These dynamics interact and influence one another, enabling the survival, development, and adaptability of living systems in constant interaction with other systems. Identity and temporal stability refer to a system’s ability to maintain its internal organization over time by conservatively managing its energy flows. This dynamic process allows it to resist disturbances and preserve its structure, as occurs with homeostasis in living organisms, where physiological mechanisms adjust the internal balance in response to changes in the intersystemic environment.

Synchronous co-emergent operations arise simultaneously and function as an interdependent assembly of activities essential for the system's operation. Eating, breathing, and interacting with other systems are fundamental examples, as they cannot be understood in isolation. In organized social systems, such as a bee colony, these functions are expressed through resource collection, communication, and internal organization, all of which operate in a coordinated manner to sustain the survival of the collective. This synchronization is equally evident in the integration of biological processes within an organism, where multiple functions occur simultaneously and sustain one another.

Sequential and escalating evolutionary activities are those that progressively emerge in response to new challenges or possibilities, whether stemming from the interaction between internal elements or from demands of the intersystem. As systems face new demands, they develop abilities that modify their structure and behavior, transforming and adapting to changing conditions. The evolution of limbs in fish for movement on land and the emergence of mitochondria through symbiotic interactions are examples of how internal and external interaction generates adaptive changes in living systems.

These three functions do not operate in isolation, but rather form a dynamic framework in which each one influences and depends on the others. Temporal stability facilitates co-emergent operations by providing a framework of equilibrium, while evolutionary activities enable adjustments and transformations as the environment changes. In an ecosystem, the identity of a biological system may be reflected in its energetic and organizational balance; co-emergent operations ensure its daily functioning, and evolutionary adaptations respond to intersystemic demands, allowing for the continuity and transformation of the system over time.

At a hierarchical level, biological systems began to exist approximately 3.8 billion years ago, following chemical evolution processes that led to the formation of fundamental molecules such as water, carbon dioxide, and complex macromolecules: proteins, nucleic acids, carbohydrates, and lipids. These molecules organized into functional systems such as ribosomes and energy transport chains, which enabled the emergence of cells, the basic units of life. Cells progressively specialized, forming tissues, organs, and organ systems, which in turn enabled the emergence of multicellular organisms with more sophisticated adaptive capacities. Organisms interact with other individuals and species, forming populations, communities, ecosystems, and ultimately the biosphere, the global biological macrosystem that sustains the complexity of life on the planet.

The evolution of multicellular systems enabled the diversification of organismal functions, optimizing energy flows and morphological organization to respond to increasingly specific demands.

The two central systems within this macrosystem include two microsystems: on one hand, plants, and on the other, animals. The emergence of complex nervous systems in animals represented a significant advancement in the ability to process information and respond to the demands of contact systems, while in plants, internal signaling mechanisms allowed for efficient coordination without the need for a centralized nervous system. These structural advances involved not only a greater utilization of energy resources, but also greater temporal connectivity between internal processes and external environmental dynamics.

Energy flows, structural morphology, and temporal connectivity are the pillars upon which biocomplexity is built in the biological macrosystem. Metabolic processes, morphological adaptations, and temporal synchronization through biological cycles and evolution demonstrate how biological systems manage complexity in a dynamic and regulated manner. The variability and stochasticity inherent in living systems allow life to maintain a dynamic balance between stability and change, optimizing the use of energy and structure to adapt to fluctuating conditions. This capacity to remain under tension while evolving into increasingly complex forms is what defines the very essence of living systems and their interrelationship with surrounding systems. This process is present, albeit with differences, in both plants and animals.[80]

In summary, the biological macrosystem is a multiscalar and dynamic evolutionary process in which life emerges, organizes itself, and transforms based on the interaction between energy flows, organizational structures, and connection times. Identity, synchronous co-emergence, and sequential evolution are the fundamental functions that allow living systems not only to survive, but also to adapt and increase in complexity within a continuous network of internal and external relationships. From the simplest molecules to the entirety of the biosphere, biocomplexity reflects a dynamic balance between stability and change, a constant interaction between the intrasystem and the intersystems that sustains life in all its forms.

[80] Biologists have highlighted communication among plants through chemical and physical signals, as well as the formation of networks and collaboration among individuals. Moreover, plants exhibit problem-solving capacities, such as the efficient search for resources, defense against predators, and the optimization of growth and reproduction, among other complex abilities.

The three activities and functions of learning - computation, mapping, and timing- in biological systems are essential for describing how these complex systems interact and evolve based on their experiences of exchange. This perspective offers a dynamic view of how biological systems process information, structure their interaction with other systems, and synchronize their activities over time.

- **Computation**: Computation is the way in which a system manages energy flow to adapt to its needs and to its interactions with other systems, optimizing the distribution and use of energy resources. It focuses on the treatment and administration of energy flows, processing the information and energetic exchanges within the system. Computation in biological systems can also be understood as the processing of information that enables organisms to review the state of the intrasystem and assess their potential losses and gains in the interaction with intersystems. Energy flows are essential for this information processing, as they provide the necessary "fuel" for the biochemical reactions and cellular processes that sustain biological computation.
- **Mapping**: Mapping is related to structural morphology, representing how systems organize, structure, and visualize their components and internal relationships, as well as how they relate to other systems. It is dynamic and continuously adjusts the system's structure based on feedback received from surrounding systems. The physical structure is, to a large extent, a tangible map of how the system relates to its energetic and biological environment. Organisms create mental or neural "maps" of other systems in order to navigate and operate in ways that ensure their well-being and survival. This capacity is evident, for example, in the ability of animals to navigate their

habitats, find food, and avoid danger. These "maps" are not necessarily visual; they can be cognitive, chemical, or based on other types of signals. Mapping is essential for learning, as it allows organisms to remember and anticipate situations based on previous experiences.

- **Timing**: Timing corresponds to temporal connectivity, managing the synchronization, duration, and sequence of interactions and events. Systems adjust their timing (for example, defensive or growth-related) based on events occurring in other systems (such as the appearance of predators or the availability of water). These responses are linked to the way the system temporally connects with other systems of contact.

From the perspective of the SK, we consider that this learning behavior is present in different modalities, both in plant and animal microsystems.[81] These microsystems possess the capacity and the need to construct maps in order to survive. These are sensitive, cognitive, and emotional maps. Here, energy-information can become entangled in various ways within the system and can be exchanged in multiple forms with other systems. These interactions are guided by choices learned through successful trial and error in the context of survival. Elements such as thinking, decision-making, bonding, and movement contribute to the adaptability and complexity of biological systems.

Life could be characterized as a complex and adaptable system capable of transforming its own energy and that of other systems through mapping, generating the necessary information

[81] In the case of plants, movements can be interpreted as biological or adaptive responses rather than conscious experiences. Although they do not feel fear or pleasure like humans or animals, they respond to stimuli from other systems in a sophisticated manner. In the SK, these responses can be analyzed as part of an interrelated system that follows behaviors of computation, mapping, and timing, which allows for a better understanding of how plants survive and thrive.

for its management via computation, and regulating the activation and deactivation of functions according to the temporal requirements of each function of the system, in a process of timing. The tripartition of learning functions - computation, mapping, and timing- shows a striking compatibility with many findings in neuroscience, as it reflects the fundamental organization of the brain and other biological systems in terms of information processing, structural organization, and temporal synchronization.[82]

In neuroscience, neuronal computation refers to how neurons and neural networks process electrical and chemical signals to generate adaptive responses. In the brain, action potentials and synaptic integration are examples of computational processes. Neurons integrate multiple excitatory and inhibitory signals and “calculate” whether they should fire an action potential.

The structural plasticity of the brain is a reflection of this mapping capacity, as it allows the reorganization of neural circuits in response to experience. The somatosensory and motor cortices of the brain are topographically organized into somatotopic maps that represent different parts of the body.

Neuronal timing is fundamental for the synchronization of brain activity and for the functional coherence between different brain regions. This timing allows the brain to coordinate the activity of distributed neural networks to generate coherent

[82] Neurotransmitters such as serotonin, dopamine, acetylcholine, glutamate, GABA, norepinephrine, and endorphins are fundamental in biological systems and are related to computation, mapping, and timing. In computation, they process information and regulate decision-making, such as dopamine in reward evaluation or serotonin in emotional regulation. In mapping, they contribute to the internal representation of the environment and internal state, with glutamate forming long-lasting synaptic connections and acetylcholine enhancing attention and spatial memory. In timing, they synchronize activities and temporal sequences, with dopamine being crucial for time perception and serotonin for circadian rhythms.

behaviors and perceptions. Brain rhythms (alpha, beta, gamma, delta waves, etc.) are an example of how the brain regulates the timing of neuronal activity.

Evolutionary theory has demonstrated how complex systems can evolve from simpler structures through gradual and cumulative processes. The evidence for evolution comes from a vast number of studies in genetics, evolutionary biology, and the fossil record, reinforcing the idea that natural selection can produce highly complex systems without the need for supernatural intervention. In evolutionism, survival depends on organisms that are best adapted to their environment, favored by natural selection based on their innate characteristics.

For the SK, the key lies not only in individual characteristics, but in the system's ability to effectively combine its internal elements (e.g., biological functions) with other external systems (other organisms or elements of the entresystem). Survival and well-being depend on these interactions and combinations.[83]

[83] In this context, the concepts of Boolean networks and fitness landscapes introduced by Kauffman offer complementary tools for modeling and understanding biological systems. Boolean networks are a mathematical model that allows for the representation of genetic interactions and regulatory networks in biological systems. On the other hand, fitness landscapes provide a powerful metaphor to understand how biological systems (and, by extension, other complex systems) explore a set of possibilities to adapt to their environment.

CHAPTER SEVEN

DESCRIPTORS OF EACH SUPERSYSTEM

Supercomplex Knowledge (SK) proposes that stability, far from being a fixed or predetermined state, is a constitutive property in complex systems. This implies that stability is neither a starting condition nor a permanent state, but the result of internal interactions, fluctuations, and continuous adjus-tments within the system. Stability is dynamic and responds to the same forces of change and evolution that generate emergent behaviors. In this sense, SK understands that stability and emergence are not opposites, but complementary manifestations of the dynamics of complex systems.

The SK approach combines behaviors that are:

1. **Dynamic:** In constant change, with flows of energy, information, and matter that interact and transform the system.
2. **Evolutionary:** Adaptive, with the ability to respond and modify according to new conditions.
3. **Circular:** Including feedback and bidirectional relationships among the components of the system.
4. **Stochastic:** Incorporating elements of uncertainty and variability, reflecting the inherent unpredictability of complex systems.

The following table presents, for each macrosystem, the descriptors of complex behavior in the energetic (energy flows), spatial (structural morphology), and temporal (temporal connectivity) dimensions according to SK.

Type of Complexity	Complexity in Energy Flows (Energetic)	Complexity in Structural Morphology (Spatial)	Complexity in Temporal Connectivity (Temporal)
Micro-particles Macro-system QUANTI-COMPLE-XITY	-Entanglement -Self-organization	-Self-organization -Superposition or multiubiquity -Stochastic morphology -Decoherence	-Uncertainty (energy-time)
Macros-copic Macros-ystem MACRO-COMPLE-XITY	-Dynamic tension -Self-organization -Circularity -Emergence (intrasystemic, entresystemic, intersystemic) and co-emergence -Resistance	-Dynamic tension -Resistance -Emergence (intrasystemic, entresystemic, intersystemic) and co-emergenc -Plasticity -Stochastic morphology	-Temporal connectivity
Biological Macro-system BIO-COMPLE-XITY	Computation -Metabolism -Autocatalysis -Cellular communication -Decision-	Mapping -Morphogenesis -Plasticity	Timing -Adaptive evolution -Collaboration

	making (Learning)		

We will now detail the different descriptors of complexity in the microparticles macrosystem.

Self-organization

In microparticle systems, self-organization may include thermal, electromagnetic, or other types of interactions. Energy flows facilitate the redistribution of energy among particles, allowing the system to explore different configurations and eventually reach lower-energy states that are more stable. In the quantum context, this behavior can be applied to phenomena such as the formation of coherent quantum states (for example, Bose-Einstein condensates[84]), where particles at ultra-low temperatures behave in a complex manner, that is, a large fraction of atoms collapses into the lowest available quantum energy state and their wave functions overlap, forming a singular macroscopic state in which the particles collectively behave as a single quantum entity. For this reason, we consider this behavior to be both energetic and spatial.

Entanglement

Quantum entanglement is a profoundly non-classical phenomenon in which the quantum states of two or more particles are related in such a way that the state of one particle cannot be described independently of the state of the other, even

[84] Bose-Einstein condensates are formed when atoms of bosons (particles that comply with Bose-Einstein statistics) are cooled to temperatures extremely close to absolute zero (0 Kelvin or -273.15°C).

if they are separated by great distances. In entangled systems, the measurement of one particle instantly determines the state of the other, regardless of the distance between them. Although this does not imply a classical energy transfer through space, it does indicate an instantaneous correlation of properties that can be used, for example, in the quantum teleportation of states.Entangled particles can exist in superpositions of states until one of them is measured. This superposition, which is fundamental to entanglement, can affect how quantum information is "stored" and "transferred," but it does not imply a flow of energy in the classical sense. In superposition, particles exist in multiple states or positions simultaneously, which can be considered as a potential energy flow distributed across these possibilities. The morphological structure of particles in superposition is, by nature, indeterminate until a measurement is made, at which point the wave function collapses into a specific state. In entanglement, the energetic interaction between entangled particles transcends physical distance, implying a non-locality in the transfer of information.

Stochastic morphology

This refers to the shapes or structures that arise randomly or unpredictably due to the inherent nature of stochastic (chance-based) processes in these systems. In the context of quantum physics and microparticle systems, this notion captures how indeterminacy and probability play fundamental roles in determining the properties and behaviors of such systems.

Heisenberg's Uncertainty Principle states that there is a fundamental limit to the precision with which certain properties of a particle, such as its position and momentum, can be simultaneously known. This introduces a fundamentally stochastic nature to the description of microparticles, since only probabilities for these values can be given. Subatomic particles, such as electrons and photons, do not behave deterministically at the quantum scale; rather, their behaviors and locations are described by quantum wave functions that provide probabilities of finding the particle in different places, which can lead to interference behaviors and complex probability distributions.

From the SK perspective, stochastic morphology reflects how the dynamic interaction between energy flows and temporal connectivity in microparticle systems gives rise to unpredictable structures, yet with emergent behaviors that can be described probabilistically. This highlights the importance of considering both energy and space in the evolution of these quantum systems.

Decoherence

Decoherence refers to the process by which a quantum system loses its properties of quantum superposition due to interactions with other systems, resulting in an apparent transition from quantum behavior to classical behavior. This phenomenon is crucial for understanding how the apparently deterministic classical world emerges from the underlying laws of quantum mechanics, which are fundamentally probabilistic and non-deterministic.

Quantum decoherence provides a mechanism to explain how coherent quantum states (where particles can be in superpositions of states) “collapse” into defined states. This process is fundamental to understanding the complexity of the transition from quantum phenomena to classical macroscopic experience. Decoherence highlights the complexity of the interactions between a quantum system and a non-quantum system. These interactions are responsible for the “loss” of quantum coherence and the emergence of classical behavior. The nature and degree of these interactions can be extremely complex and are influenced by factors both internal and external to the system.

During the decoherence process, energy flows play a crucial role. The interaction of the quantum system with other non-quantum systems involves an energy transfer, which can be generated by collisions, thermal fluctuations, or any external disturbance. As the system exchanges energy, the quantum coherences between the states are destroyed, since the energetic fluctuations induce random phases in the superposed quantum states. The structural morphology of a quantum system can be significantly altered during decoherence. Initially, in a coherent quantum state, the structure of the system is defined by superpositions and quantum interferences. However, as decoherence progresses, these superpositions are destroyed and the structure of the system becomes more classical.

From the SK perspective, decoherence is interpreted as a phenomenon in which the energetic interaction of the quantum system with its environment leads to a morphological reorganization that generates a transition from complex quantum behaviors to a more stable macroscopic state. This reflects how the interaction between energy, space, and time can transform the nature of the system.

Superposition

A particle in superposition is not confined to a single position in space, but can occupy multiple positions simultaneously, which challenges the classical notion of precise localization. We understand this "multiubiquity" by stating that its location and state depend on its temporal connectivity (TC) and structural morphology (SM) within the system.

In temporal terms, superposition introduces a non-linearity in the evolution of microparticle systems. The collapse of the superposition, that is., the moment when the particle adopts a defined state upon being measured, is a temporal phenomenon that marks a before and after in the behavior of the system.

Uncertainty (energy–time)

This descriptor establishes that certain pairs of physical variables, such as position and momentum, or energy and time, have an uncertainty relationship such that the precision with which one can be measured implies a limitation in the precision with which the other can be known. Uncertainty in microparticle systems, particularly the energy–time uncertainty relationship, is a crucial descriptor of complex behaviors and has profound implications in the temporal dimension of these systems. This relationship is an expression of Heisenberg's uncertainty principle, which in its energy–time form states that it is not possible to simultaneously and precisely determine both the energy of a system and the time during which that energy is maintained.

This principle has practical consequences in phenomena such as transitions between energy levels in atoms. The energy–time uncertainty implies that such transitions do not occur instantaneously, but rather involve an intrinsic indeterminacy in the time these transitions take, which results in observable effects such as the spectral broadening of emission and absorption lines. These effects not only reveal the probabilistic nature of quantum systems, but also show how temporal uncertainty affects the predictability and stability of those systems.

From the SK perspective, the energy–time relationship not only highlights the limitations in our ability to measure quantum systems, but also emphasizes the dynamic interaction between energy and time as factors that shape system complexity. This temporal uncertainty introduces constant fluctuation in the temporal connectivity of microparticles, contributing to the overall complexity of the system and affecting its structural morphology and its evolution over time.

We will now detail the different complexity descriptors in the macroscopic macrosystem.

Energetic Descriptors

Dynamic Tension

This refers to the interaction between stability and variability in a complex system. Instead of seeking a static and stable state, complex systems maintain a delicate balance between the need to preserve a certain degree of coherence and stability, and the ability to adapt to external changes and challenges. This energy-informational balance is crucial for understanding the dynamics of complex systems, as it enables them not only to respond to unpredictable events, but also to evolve in accordance with other systems.

If a system becomes too stable, it may grow rigid and incapable of adapting to new circumstances. On the other hand, if it becomes too variable, the system might descend into chaos and lose its structure. Dynamic tension, therefore, refers to the continuous pursuit of an optimal balance between stability and variability in a complex system. That is why, for the SK, describing and observing both stability and emergence, as well as resistance, is so important. Without understanding and obser-ving a system's stability, signs of emergence may go unnoticed. Dynamic tension provides the context and foundation needed to evaluate changes in the system and to detect emergent properties that may arise. If the system fails to maintain stability, emergence might not be perceived, or worse, it could lead to the system's instability or collapse.

Therefore, describing and observing the dynamic tension of a complex system is essential for understanding and detecting the emergence of new properties or behaviors. This includes understanding how the components of the system interact with one another, how balance is maintained, and how changes occur within the system.

In this way, the description and observation of dynamic tension make it possible to understand how a system's components interact, how energy-informational balance is sustained, and how changes unfold within the system.

From the SK's perspective, a macroscopic system's ability to sustain this dynamic tension is what enables it to adapt to new conditions without losing its internal coherence. This tension is key to the evolution and resilience of complex systems, as it allows them to find new balances as they interact with surrounding systems.

Resistance

Alongside tension, resistance emerges as another essential aspect of complexity. It refers to the ability of a complex system to maintain its structure and function when faced with internal or external changes and disturbances. This resistance is fundamental to ensuring efficient functioning and preventing system instability or collapse. Resilience, which forms part of resistance, refers to the system's ability to recover after changes and disturbances. In essence, complex systems maintain their energetic and structural stability through various regulation and adaptation mechanisms. "Robustness" and "fragility" are generally associated with this descriptor, considering it especia-lly in relation to resistance and the system's capacity to handle disturbances. The relationship between these elements is what allows a complex system not only to withstand changes but also to thrive within complex dynamics of linkage.

Emergence

Emergence, in turn, is the consequence of the interplay of energy flows or changes in structural morphologies, occurring when the elements of a complex system interact with each other, when elements from another system interact with the first, or when two or more systems interact with each other. For the SK, emergences do not arise spontaneously nor are they the result of a determined cause; rather, they are the consequence of the turbulence arising from the interplay between components or between systems.

Emergent behaviors are characteristics that arise from the system as a whole and cannot be directly attributed to any of its individual components. These behaviors, as previously noted, are the result of interactions between energy flows and the organization of the system's elements.

Emergence can be seen as a source of innovation and adaptability in complex systems, enabling creative responses and solutions to changing situations. This process is fundamental for the evolution of complex systems, as it grants them the ability to generate new adaptive behaviors. The appearance of emergent behaviors in a complex system can be both positive and negative.

On the positive side, emergent behaviors can lead to improvements and unexpected outcomes that may benefit the system. These behaviors can arise through the interaction and cooperation of the system's components, resulting in greater adaptability, efficiency, and resilience. However, on the negative side, emergent behaviors can also have adverse effects, causing imbalances, instability, and even collapses, potentially leading to the system's disappearance. These challenges may result from the interaction of system components in an unintended or unpredictable manner. Ultimately, the evaluation of emergent behaviors in a complex system must be based on a detailed analysis of their consequences and the specific network of systems in which they occur. It is not possible to generalize whether they are inherently positive or negative, as they depend on multiple factors and variables.

For the SK, it is possible to conceive different types of emergencies in complex systems, which can occur either within a system or as a result of interaction with external systems. These emergencies can give rise to complex and circular behaviors, with both positive and negative effects.

a) Intrasystem Emergence: This type of emergence refers to interactions that occur within a particular system. These interactions involve the elements that are part of the same system and their mutual influences. For example, in an ecosystem, the interactions between different species and their impact on the ecosystem's balance would be considered intrasystem interactions.

b) Cross-System Emergence: Cross-system emergence refers to interactions that occur between different systems, which can have a significant effect on the dynamics of the systems involved. An example of this would be the interaction between an economic system and a plant microsystem, which may have consequences for both the economy and other interconnected systems.

c) **Intersystem Emergence**: This refers to interactions that occur between the components of one system and the components of other systems. It describes the connections between different elements of different systems, which is important for understanding how effects are transmitted across interconnected systems. For example, in the context of an epidemic, the disease (element of the health system) impacts components of other interconnected systems, such as the disruption of in-person classes (element of the educational system).

d) **Coemergence**: This concept refers to the idea that, in the exchange between different systems or elements, a joint or mutual emergence arises. Instead of considering emergencies as isolated or independent events, it is recognized that systems interact with each other and that emergencies can arise as a result of these complex interactions. The notion of coemergence highlights the interdependence and interconnection of systems, where actions or changes in one system can trigger responses or consequences in other systems. Example: Unplanned urban development and climate change can influence each other in a complex manner. On the one hand, intensive urban development can contribute to climate change through greenhouse gas emissions and the reduction of green areas. On the other hand, the effects of climate change, such as rising sea levels and heat waves, can have a direct impact on cities, affecting urban planning, public health, and infrastructure.

Each type of emergence can also manifest in synchronous or sequential modalities, depending on the particular dynamics of the systems involved and the energetic, spatial, and temporal interactions between them. It is important to note that coemergence is always synchronous, while other types of emergence can adopt either synchronous or sequential modalities, depending on the cross-system interactions.

The synchronous modality of emergence occurs when functions or interactions arise simultaneously, interdependent, and necessary for the system's operation and survival. In this context, synchronous convergences represent a set of critical functions that cannot be separated. For example, in living systems, processes such as breathing, feeding, and relating to others were synchronous coemergences whenever these activities were integrated simultaneously in a state of functional interdependence that keeps the system in balance.

On the other hand, sequential emergencies arise progressively, often in response to internal or external conditions that require adaptive or functional escalation. These emergencies are essentially observed in intrasystem and cross-system processes, where emerging activities occur in a logical or temporal order. For example, in a living system, the ability to develop specific skills like walking or speaking may arise as an adaptive sequence as the system interacts with its environment.

In short, for the SK, emergence is not the result of isolated mechanisms but of imbrication processes, where relationships between system elements form dynamic structures. These imbrications not only connect the parts but also reconfigure them in ways that transcend their original characteristics, giving rise to emergent properties.

Circularity

Circularity describes a process in which the system's elements influence and modify each other through the exchange of energy flows, thus creating a continuous feedback cycle. This concept captures the essence of how, in interaction, not only is another element altered, but the original element also undergoes modification, reflecting an interdependence and dynamic coevolution within the system. This concept is fundamental in complex systems because it shows that each interaction between elements is not unidirectional but generates a reciprocal impact.

This process reflects the interdependence and dynamic coevolution of the system's components. Each energy exchange within the system can be amplified or attenuated over time due to this continuous cycle, allowing the system to adapt and the emergence of new properties. Circularity not only implies that the individual elements of the system interact and modify each other, but also that the system as a whole reconfigures as these interactions are repeated and evolve.

From the SK perspective, circularity is key to understanding how complex systems maintain their internal coherence and adaptability. Through this process, the system can continuously adjust to new conditions and challenges without losing its fundamental structure. This feedback cycle is what gives the system its ability to evolve and respond dynamically to disturbances.

Self-organization

Self-organization describes the inherent ability of these systems to manage and distribute their internal energy autonomously and spontaneously, without the existence of a central rational control. This process is characterized by local and decentralized interactions between the system's components, where structures form spontaneously. This capacity is characterized by processes that are partially stochastic and emergent, where organization is not the result of a predefined design, but rather the spontaneous and self-regulated interaction of its components.

Complex systems use their internal energy to self-regulate and adapt, responding flexibly to both internal and external needs and conditions. The system's ability to reorganize efficiently depends on its capacity to manage energy fluctuations and redistribute energy in response to disturbances. This management and redistribution of energy occurs with a significant degree of randomness, allowing systems to maintain a dynamic equilibrium and operate efficiently. Therefore, self-organization is a fundamental pillar in understanding how complex systems function, evolve, and maintain cohesion, highlighting the importance of spontaneity in the emergence and maintenance of order within complexity.

Self-organization is, therefore, a fundamental pillar in understanding how complex systems operate, evolve, and maintain cohesion. It emphasizes the importance of spontaneity and flexibility in the emergence and maintenance of stability within complexity, allowing systems to adapt and survive in changing and challenging situations.

Spatial Descriptors

These descriptors emphasize how space is not merely a passive container for a system's activity but an active and dynamic participant in complexity processes.

Plasticity

Plasticity, as a spatial descryptor in complex systems, implies an inherent adaptability and malleability in spatial configuration. This characteristic allows space not only to reconfigure itself in a process of formation in response to internal and external variations but also to act as an active shaping agent.

The flexibility of space is crucial for the survival and efficiency of these systems since it limits and conditions energy flows, influencing how these flows interact and distribute within the system. This duality of being both configured and configurator highlights the importance of space in the continuous adaptation and evolution of complex systems, playing a fundamental role in determining how and why systems behave and change the way they do. Therefore, space is not just a passive stage where interactions occur but actively influences how and why systems behave and change the way they do. Spatial plasticity, therefore, is not merely a matter of passive reorganization but an active dynamic that significantly contributes to the system's overall shape and function.

Stochastic Morphology

This descriptor addresses the unpredictability and element of randomness in the spatial organization of complex systems. Stochastic morphology suggests that spatial events do not always follow linear or predictable trajectories but are influenced by random and probabilistic factors. Within this framework, linear, reticular, arboreal, topological, radial, and fractal forms represent different manifestations of how space can be structured in complex systems. Indeed, other forms appear in the universe, such as spirals, donuts, hexagons, cylinders, pentagons, among others. These forms and structures are examples of how physical laws, mathematical principles, and biological processes interact to create the complex variety of shapes with distinct particularities that we observe in the universe.

Furthermore, there is a close link between these forms and energy flows, demonstrating how nature tends to favor structures and shapes that are optimal for the transfer, conservation, and efficient use of energy. These relationships between structural forms and energy flows highlight how the principles of thermodynamics, mechanics, electromagnetism, and other areas of physics are fundamental to understanding and designing systems, both in nature and the human-made world. Ultimately, energy flows in interaction generate structural forms, but structural forms condition the dynamics of energy flows; therefore, the relationship is circular.

Structural Forms:

- Linear: Linear behaviors in complex systems refer to structures or processes that develop in a one-dimensional ma-nner. These structures are characterized by a clear and direct progression from one point to another, resembling a straight line.
- Reticular: Reticular matrices refer to structures organized in a network or mesh form. These morphologies emphasize the interconnection and spatial distribution within a system, where nodes (points) are connected by links (lines), forming an interwoven structure.
- Arboreal: Arboreal forms are characterized by their branching structure, similar to that of a tree. In these structures, a central point or root bifurcates into several branches, which can further divide into more branches, creating a hierarchical and branched structure.

- Topological: Topological forms refer to changes in the spatial structure of an object or system that preserve certain fundamental properties. In topology, a branch of mathematics, these transformations allow an object to deform continuously (such as stretching or compressing) without breaking it or merging its separate parts. The key property here is that, despite changes in shape or size, certain characteristics of the object remain unchanged, such as connectivity and the number of holes.
- Laminar: a multilayer structural arrangement comprising interconnected strata, which enables the integration of concurrent processes across distinct levels, thereby fostering adaptability, complexity, and relational emergence.
- Radial: Radial architectures in complex systems describe structures or processes that expand outward from a central point in multiple directions, similar to the spokes of a wheel. These forms are characteristic of systems where a central core radiates influence or receives inputs from multiple sources, emphasizing the importance of the center as a control or coordination point from which activity extends outward.
- Fractal: Fractals are structures that exhibit repetitive forms at different scales. They are unique in their property of self-similarity, meaning that each small part of a fractal resembles the whole. This characteristic of repetition at different levels of magnification reveals an underlying complexity in what might initially appear to be a simple structure.
- Spirals: A distinctive form characterized by its curve around a central point and its progressive expansion inward or outward. Spirals are present in galaxies such as the Milky Way and in meteorological phenomena like hurricanes. This shape facilitates the transfer and movement of matter and energy through rotating systems.

- Toroids (Donuts): A three-dimensional shape with a hole in the center. Toroids are observed in magnetic fields, such as those generated by the Earth, or in tokamaks designed for nuclear fusion. Toroidal shapes are optimal for containing and directing energy flows efficiently.
- Hexagons: A six-sided shape with six equal angles. The most notable example is the structure of honeycomb cells, which maximize storage space with the minimum amount of material. Another example is the hexagonal storm pattern in the atmosphere of Saturn around its north pole. These shapes offer a combination of structural strength and space efficiency.
- Cylinders: Three-dimensional shapes with two identical circular bases connected by a curved surface. Cylinders are present in tree trunks, long bones in animals, and human-made structures such as pipes and columns. They provide strength and support while using material efficiently.
- Pentagons: Pentagonal morphologies refer to structures organized around a five-sided geometric shape. Although less common on a large scale, pentagons are fundamental in chemistry, as seen in the structure of some viruses.[85]

Temporal Descriptors

Temporal Connectivity

Connectivity, being a dual descriptor by nature (connection-disconnection), refers to the fluctuating dynamics of interactions and synchronizations between its components over time. This descriptor captures how the system's elements align and coordinate at certain moments, while at other times they operate independently or on different temporal scales. This

[85] From Complexity Sciences, they include as a causal cascade the butterfly effect or domino effect, and from Complex Thinking, the (recursive) loop.

flow, between synchronization and autonomy, allows the system to maintain a balance between coherence and flexibility.

The alternation between moments of high connection and moments of disconnection is fundamental for the system to not only respond collectively to critical events but also allow its components to act independently when necessary, avoiding rigidity that could compromise its adaptability. Therefore, temporal connectivity is crucial for the system's adaptability and resilience, facilitating effective coordination at key moments while also ensuring the independence and diversity of components to address complexity and avoid overloads or interferences.

This temporal flow ensures that the system is neither permanently synchronized nor completely disconnected, but rather fluctuates between both states, optimizing its ability to face challenges and seize opportunities in various situations and temporal scales.

COMPUTATION

Within the biological context, computation refers to the processing of information and decision-making that occurs at the cellular and molecular levels. This concept encompasses essential behaviors for generating and maintaining complexity in biological systems, such as autocatalysis, metabolism, and cellular communication.

Autocatalysis

Autocatalysis, as a generator of complexity in biological systems, refers to a chemical process in which a product of a reaction acts as a catalyst for the same reaction, creating a positive feedback loop. This cycle amplifies and diversifies chemical reactions within the system, allowing for greater complexity and adaptability. Autocatalysis is fundamental for the emergence of complexity in biological systems, as it facilitates self-organization and the evolution of interconnected metabolic networks.

Metabolism

Metabolism allows the conversion of nutrients into usable energy (ATP), which is then used to drive cellular activities, including signaling, repair, and reproduction. It is a complex set of vital chemical reactions that transform nutrients into energy and building blocks for the cell while eliminating metabolic waste. From the perspective of biological computation, metabolism can be understood as an interconnected and precisely regulated autocatalytic network, providing the system with the resources and energy it needs to maintain its function, such as growth, repair, and cellular reproduction.

Cellular Communication

In cellular communication, cells not only perform metabolic processes internally but also exchange information with other cells and respond to signals from other systems. This information exchange is essential for coordinating cellular activities in tissues and organs and ensures the cohesive functioning of multicellular organisms. Cellular communication is crucial for the coordination of cellular activities in tissues and organs, allowing multicellular organisms to function cohesively. This process involves various molecular signals, receptors, and signaling pathways, which can be considered as "biological computation systems" where information is processed and translated into specific cellular responses.

MAPPING

Mapping in the biological macrosystem includes behaviors such as morphogenesis and plasticity, which are crucial processes for understanding how systems develop and respond to various situations.

Morphogenesis

Morphogenesis refers to the biological process that determines the shape and structure of organisms and biological structures. This process is a key descriptor of biological complexity because it involves the interaction of multiple factors, such as genetic and chemical ones, working together to organize and shape tissues and organs, from the cellular level to the level of complete organisms. Morphogenesis not only defines initial forms during development but also allows biological structures to maintain their structural integrity despite influences from other systems. Therefore, it is essential to understand how living organisms achieve stability in their forms, even when constantly interacting with changing situations.

Plasticity

Plasticity, in the context of structural morphology, refers to the ability of organisms to alter their shape, structure, or phenotypic expression in response to changes in internal or external conditions while interacting with other contact systems. Changes in morphology occur during the growth and development stages of an organism, in the ability of a genotype to produce different phenotypes, and in animals, especially humans, neural plasticity refers to the brain's ability to reorganize itself in response to experience, learning, or injury.

This adaptability is fundamental for learning, memory, and injury recovery.

TIMING

Timing in biological systems encompasses the synchronization of key behaviors, such as adaptive evolution and collaboration, both fundamental to the dynamics of living complex systems. These behaviors reflect how living beings adjust their activities and responses over time, in response to challenges and opportunities presented by their changing environments.

Adaptive Evolution

Adaptive evolution is the ability of complex systems to interact with contact systems and adjust over time. This ability implies that systems are not mere passive receivers of energy flows but dynamic entities that actively modulate and adapt their use and response to energy, depending on external and internal changes. Adaptive evolution refers to the process by which organisms adapt to other systems over generations through changes in their genetic characteristics.

This process is essential for survival and reproduction in a changing intersystem and is intrinsically linked to timing, as evolution allows species to develop adaptive responses to seasonal cycles, climate changes, and other temporal events. Moreover, it shapes the life cycles of organisms, including their reproductive and growth rhythms, to optimally coincide with the opportunities and temporal challenges in coexistence with other systems.

This adaptability is a continuous series of adjustments and optimizations, enabling these systems not only to survive but also to thrive under changing conditions. Therefore, adaptive evolution is a dynamic interaction between the system and its contact systems, where adaptation is not merely a reaction but a proactive evolution, allowing continuous evolution that aligns with the changing demands and challenges of reality.

Collaboration

Collaborative behavior emphasizes a more organized and adaptable level of interaction, where the integration of diverse roles and the dynamic adaptation of strategies contribute to solving complex problems and fostering innovation within the system. Collaboration enables organisms to increase their biological fitness and improve their chances of survival by working together in a coordinated manner.

Collaboration can occur within the same species, as in cooperative hunting among wolves, or between different species, as in the symbiotic relationship between flowers and their pollinators. In the context of timing, collaboration highlights how biological entities synchronize their activities in a way that benefits all participants, such as in the feeding and sleeping cycles in social animals or in the synchronized blooming of plants.

CHAPTER EIGHT

MICROSYSTEMS, SYSTEMS, AND SUBSYSTEMS

SYSTEMS WITHIN THE MICROPARTICLE MACROSYSTEM

For Supercomplex Knowledge (SK), microparticle systems can be classified and divided into fermionic and bosonic systems, based on how energy flows circulate and how they interact with structural morphology. This division is grounded in the principles of quantum and particle physics.

Fermions include electrons, protons, neutrons, and quarks. What distinguishes fermions is that they obey the Pauli Exclusion Principle, which states that two identical fermions cannot occupy the same quantum state simultaneously. This has profound implications for how energy flows circulate and how matter is structured at atomic and molecular scales, affecting the morphology of matter. Complexity in fermionic systems is manifested in the diversity of chemical elements and in the complex electronic interactions that determine conductivity, magnetism, and other material properties.

Bosons, on the other hand, are particles that act as force carriers and enable interaction between fermions. These include photons (light and other electromagnetic radiation), gluons (responsible for the strong nuclear force), and the Higgs boson (associated with the Higgs field and particle mass). Unlike fermions, bosons can occupy the same quantum state, which enables phenomena such as Bose-Einstein condensation, where multiple bosons occupy the same state, leading to distinct macroscopic behaviors such as superfluidity and super-conductivity.[86]

Fermionic systems exhibit complexity in their structural organization and in the constraints imposed by the Pauli Exclusion Principle, leading to a rich variety of physical and chemical phenomena. On the other hand, bosonic systems display complexity through their capacity to form coherent and macroscopic states, which also give rise to unique phenomena and technological applications. Each presents distinct challenges and complex behaviors within its respective domain.

The following cross-table illustrates the differences in complexity between bosons and fermions, highlighting how each type of particle contributes to complex phenomena in their respective fields.

Comparative Table of Complexity Between Fermions and Bosons

ASPECT	**FERMIONS**	**BOSONS**
Definition	Particles that constitute matter, such as electrons, protons, neutrons, and quarks..	Particles that mediate fundamental forces, such as photons, gluons, W and Z bosons, and the Higgs boson.
Fundamental	Obey the Pauli	Not subject to the

[86] This division and understanding of microparticle systems are fundamental in fields such as materials physics, nanotechnology, and particle physics, and have practical applications in technology, medicine, and other scientific and engineering domains.

Principle	Exclusion Principle: two identical fermions cannot occupy the same quantum state simultaneously.	Pauli Exclusion Principle: multiple bosons can occupy the same quantum state.
Effects on Structural Morphology	Mutual exclusion generates organized structures and levels of complexity in atoms and molecules, affecting electronic structure and chemical properties.	The ability to share the same state enables coherent states and unique macroscopic phenomena, such as Bose-Einstein condensates.
Complexity in Energy Flows	Restrictions on energy state occupancy create discrete levels and complex electronic interactions.	Bosons can condense into the lowest energy state, enabling coherent energy flows and phenomena such as superconductivity..
Contribution to Macroscopic Complexity	Fermion organization accounts for the diversity of materials and physical properties observed in nature.	The aggregation of bosons in coherent states produces phenomena that challenge classical intuition and open paths to new phases

		of matter.
Fundamental Interactions	Participate in strong and weak interactions, and are affected by electromagnetic and gravitational forces.	Mediate fundamental forces (electromagnetic, strong nuclear, and weak nuclear) and enable interactions between fermions.

This table reflects how fermions and bosons contribute differently to complexity within microparticle systems, in alignment with the principles of SK. By highlighting the differences in how energy flows circulate and how they interact with structural morphology, it becomes clear how essential these particles are in the formation and evolution of complex systems. In this regard, it would not be accurate to claim that one system is more complex than the other; rather, both types of particles contribute distinct and complementary forms of complexity to the universe. While fermions form the "architecture" of matter, bosons are responsible for the "interactions" that sustain and transform that architecture. SK emphasizes the dynamic and stochastic interrelation between these fundamental components.

SYSTEMS WITHIN THE MACROSCOPIC MACROSYSTEM

With regard to the macroscopic macrosystem, the systems include:

1. **Galactic:** Systems that encompass entire galaxies, their structures and dynamics, as well as the phenomena occurring

within them, such as star formation and interactions between galaxies.

2. **Stellar:** Involving stars and their life cycles, from formation in nebulae to final stages as white dwarfs, neutron stars, or black holes, including multiple star systems.

3. **Solar (Planetary) Systems:** Focusing on planetary systems, such as our Solar System, and including the central star (e.g., the Sun), planets and their moons, asteroids, comets, and other minor bodies, as well as the dynamics among these bodies.

4. **Individual Planetary:** Referring to specific planets, both within our solar system and exoplanets in other stellar systems, including their characteristics such as geology, atmosphere, magnetosphere, and potential biospheres.

5. **Satellite:** Pertaining to bodies that orbit planets (natural or artificial), including moons, artificial satellites, and orbital debris.

6. **Terrestrial (Geological):** Encompassing Earth-related phenomena and characteristics, including geology, plate tectonics, volcanism, and mountain formation.

7. **Hydric (Hydrological):** Referring to bodies of water and aquatic systems, such as oceans, seas, lakes, rivers, and aquifers, including water dynamics, hydrological cycles, and oceanographic processes.

8. **Atmospheric-Aerial:** Including the atmosphere and the meteorological and climatic phenomena occurring within it, such as wind, precipitation, storms, and long-term climate behaviors.

9. **Chemical (Macroscopic Chemical Compounds):** Including substances and chemical compounds in macroscopic quantities, encompassing pure materials, mixtures, solutions, and their interactions in chemical reactions observable at the human scale.

This also involves processes such as corrosion, combustion, and the synthesis of new materials.

10. Macroscopic Molecular and Atomic: Although individual molecules and atoms are microscopic, their collective effects manifest in macroscopic phenomena. This includes states of matter (solid, liquid, gas), phase transitions, and material properties derived from atomic and molecular arrangements, such as crystallization and electrical conductivity.[87]

Each macroscopic system has a specific structure that can change over time due to energy flows and interactions with other systems. Moreover, structures can be physical (such as mountain formation), chemical (such as crystallization), or astronomical (such as galaxy formation).

SYSTEMS WITHIN THE BIOLOGICAL MACROSYSTEM

For the SK, within the biological macrosystem, two major microsystems can be identified:

- Plant microsystem
- Animal microsystem

From this classification, two questions arise:

1. Why not include a human microsystem?
2. Why not add a cyber-intelligent microsystem that encompasses machines with artificial intelligence?

[87] Different perspectives can be considered regarding where to draw the line between the macroscopic and the microscopic, especially in the context of modern physics, where the distinction between the two can become blurred. If we consider atoms as part of the macroscopic system, we do so recognizing that, although they are individually microscopic entities, the collective effects and emergent properties of atoms are fundamental to the constitution and behavior of macroscopic systems.

First, the choice of these two microsystems responds to a functional criterion based on modalities of complexity. Second, the human being is not considered an independent microsystem within the biological macrosystem because, although it presents higher levels of complexity and sophistication than other animals, its modality of complexity is not qualitatively different. The capacity for meta-observation, the construction of culture, and technoengineering are advanced expressions of processes already present in other organisms, not a rupture with them.

From this perspective, the SK acknowledges human uniqueness without isolating it from the evolutionary network of living systems. Continuity is maintained among all biological systems in terms of their energy flows, structural morphology, and temporal connectivity.

Third, a possible cyber-intelligent microsystem could not be considered completely autonomous, even if it were to reach advanced levels of operational independence. The SK anticipates that artificial intelligence and robotics will evolve to become highly independent systems in relational terms, but they will never be absolutely autonomous systems, as they will always be embedded in networks of interdependence with other complex systems.

The future challenge of the SK will be to describe the different degrees of relational independence and to establish criteria for evaluating the extent to which a cyber-intelligent system has reached a significant level of agency within the network of supercomplex systems.

Returning to our microsystems (plant and animal), each of these microsystems has its own dynamics, morphology, and organization, which determine differences in their levels of complexity.[88]

The animal microsystem, by contrast, is organized around an indirect energy relationship that depends on the ingestion and transformation of organic matter from other living beings, which implies a greater need for mobility and exploration. Its morphological structure is more dynamic and adaptive, allowing for the specialization of organs and functions through the development of nervous, muscular, and skeletal systems that optimize resource acquisition, defense, and reproduction. Temporal connectivity in animal organisms is more flexible and subject to learning and adaptation processes, with an enhanced ability to respond to immediate stimuli, allowing them to modify behaviors based on experience and memory. Their communication becomes highly diversified, incorporating not only chemical and electrical signals but also gestural and auditory expressions, and in some species, complex linguistic structures capable of conveying symbolic information about past events, future intentions, and specific social configurations.

From the perspective of SK, the difference in complexity between the two microsystems lies in the variability of their energy flows, the flexibility of their structural morphologies, and the diversity of their temporal connectivities. The plant microsystem exhibits greater stability in its energy exchanges due to its reliance on a constant source such as sunlight, which

[88] Although fungi and microorganisms exhibit distinct characteristics, they do not constitute an entirely different mode of complexity from that of the plant and animal microsystems. Fungi, through their formation of symbiotic networks with plants and their key roles in plant ecosystems, can be understood as a subsystem of the plant microsystem. On the other hand, microorganisms encompass a wide functional diversity, with species that interact with both the plant microsystem (e.g., cyanobacteria) and the animal microsystem (e.g., gut microbiota). From this perspective, rather than defining a separate microsystem, the SK considers it more appropriate to analyze these organisms based on their interactions within existing systems, thus avoiding unnecessary fragmentations and emphasizing interdependence as a key principle of biological complexity.

leads to a morphology characterized by more homogeneous behaviors and a temporal connectivity regulated by predictable rhythms. In plants, complexity arises from modular interconnection and the optimization of long-term energy flows.

The animal microsystem, by contrast, is subject to more abrupt variations in resource availability, which favors the development of more dynamic and flexible structures, with greater reliance on computation, mapping, and timing. In animals, complexity increases through decision-making capacity, behavioral variability, and the construction of social relationships with growing levels of abstraction and symbolization.[89]

On the other hand, within the animal microsystem, it is possible to identify the following systems:

- self-aware self system
- socio-relational system
- mental system for organizing behaviors and intangible products
- symbolic system
- technological system

Technological subsystems:
a) techno-engineering
b) cyber-analogical

Self-aware self system

This system is related to self-perception, self-reflection, self-awareness, and introspection. For the SK framework, this recognition of the "self" as a distinct entity underlies the capacity for self-regulation and for cognitive, emotional, and

[89] Throughout the development, we will highlight the particular characteristics and differences of human behavior in relation to other animals, emphasizing the distinctions in complexity that it implies and entails.

social development, making the self-aware self system the starting point for understanding other complex biological processes. It encompasses outputs such as dreams, ideas, desires, self-control, self-concept, and metacognition. It is constructed through the emergence of self-awareness, which arises from the synthesis and interpenetration of internal phenomena (thoughts, emotions, perceptions) and stimuli from external systems.

This temporal dichotomy between the internal and the external allows humans (and some animals to a lesser extent) to perceive material reality outside the body, which leads to the recognition of oneself as an entity distinct from other systems and individuals, even though this separation should not overlook the interweaving between systems.

Self-awareness enables us to perceive our body as a distinct and autonomous entity from other systems. This system has been, and continues to be, studied by various disciplines such as psychology, philosophy, and neuroscience, which explore topics like the formation of a unified self-conscious identity.[90]

The skin acts as the most immediate physical boundary that defines individuality. It is the container of the body and the first point of contact with the external world. This physical boundary also carries psychological and symbolic weight, as it represents the first level of awareness of oneself as a being separate from the environment.

Several animals, in addition to humans, display capacities that suggest a similarly complex functionality in terms of self-awareness. Some of the most notable include:

[90] Neuroscience provides an additional perspective by investigating the neural correlates of consciousness and how the brain constructs the experience of the self and the perception of the body. Research in this field has identified specific brain areas and networks that contribute to bodily awareness, such as the insula and the somatosensory cortex, which are essential for processing sensory information and the perception of one's own body.

1. Great apes (chimpanzees, bonobos, gorillas, and orangutans): These primates exhibit remarkable long-term memory, focused attention, and the ability to plan ahead, such as using tools in anticipation of future needs.
2. Dolphins: Known for their intelligence, dolphins can recall past events, pay attention to complex tasks, and display behaviors that suggest planning and imaginative play.
3. Elephants: Elephants have exceptional memory, are capable of remembering water routes for years, and show attentiveness and care in their social interactions. They also exhibit signs of mourning and other complex behaviors.
4. Crows and other corvids: These birds are known for their problem-solving abilities, tool use, spatial memory (such as remembering where food is hidden), and behaviors that suggest some form of future planning.
5. Octopuses: Despite being invertebrates, octopuses possess a high degree of intelligence, can learn and remember how to solve mazes and problems, and have shown signs of playful behavior, suggesting a form of imagination.

These animals demonstrate that functional complexity in terms of memory, attention, and imagination is not exclusive to humans, and that other beings also possess advanced cognitive capacities.

Delving deeper, this system is built upon the emergence of self-awareness, which arises from the synthesis between internal phenomena, such as thoughts, emotions, and perceptions, and stimuli from surrounding contact systems (external inputs). This dichotomization of reality enables humans (and to a lesser extent, certain animals) to recognize themselves as distinct entities, separate from adjacent systems and other individuals. This recognition functions as a boundary of subjectivity while simultaneously allowing the perception of other systems beyond one's own corporeality. It suggests that consciousness, or the conscious perception of the self, enables the recognition of the body as an entity distinct from other systems, thereby establishing a differentiation between the "self" and the "other."

Memory, attention, and imagination are three fundamental activities that involve timing and temporal connectivity in biological systems, especially in those possessing a self-aware consciousness. These activities enable individuals not only to maintain temporal coherence in their experiences and actions but also to integrate and manipulate information across time, thus facilitating greater complexity in interaction with other systems and in self-reflection.

Memory is linked to the past, enabling individuals to recall and relive previous experiences and learning. Attention is oriented toward the present, allowing for the perception of and response to immediate stimuli. Imagination projects into the future, enabling the anticipation of scenarios and the planning of actions. These temporal processes are interrelated and essential for the coherence and functionality of the self-aware "I".

Memory, which allows us to encode, store, and retrieve information from our environment through what are known as "multi-store memory systems" (sensory memory, short-term memory, and long-term memory), is linked to the past, enabling the re-experiencing of previous learning and experiences. Attention is centered on the present and is closely related to perception, being influenced by both extrinsic (external) and intrinsic (internal) factors in response to current stimuli. Moreover, attention can be categorized into selective, divided, and sustained attention, depending on the mechanisms involved.

Imagination, in turn, projects toward the future, allowing individuals to anticipate scenarios and plan actions. These temporal processes are interrelated and essential to the coherence and functionality of the self-aware "I."

From our perspective, the configuration of the self-aware system is performative. That is, self-awareness emerges from the energetic feedback between internal processes and external stimuli, influenced both by the presence of neurotransmitters and by the capacity of the will to alter the natural outcome of those connections. This dynamic shapes the way we relate to contact systems, through intricate interactions modulated by social mandates, behavioral norms, customs, and other systemic constraints.[91]

This is precisely where the complexity of this system arises: the vast number of contact systems, each with their own energy flows, exert both positive and/or negative influences on the self-aware "I." Within the framework of these interactions emerge desires, purposes, aspirations, beliefs, values, fears, dreams, self-esteem, self-control, self-concept, and metacognition.

In the domain of the conscious and rational self, "energy flows" can be understood as the various motivational forces and cognitive processes that drive the pursuit of personal goals, aspirations, and long-term objectives; emotional regulation in accordance with social norms and situational demands; cognition and behavior; problem-solving and decision-making

[91] What about behaviors commonly referred to as unconscious? Our perspective on complexity is operational and functional. In this sense, we understand that if such behaviors can be dissociated and disaggregated from other behaviors, and if they actively participate as part of the energy flows within a complex system, they may be considered relevant. However, concepts such as repression, lack, libido, or drive, among many others, require operationalization; that is, they must be made suitable for use in the description and modeling of how they influence the dynamics of a complex system. The aim is for these variables to eventually be combinable with others. In this regard, we maintain that it is not possible to reduce complex human behaviors and experiences to a few underlying causes, such as sexual desires or the structure of language.

based on logic and evidence; the ability to take another's perspective; self-evaluation and the conscious questioning of one's own beliefs and attitudes. More specifically, this includes the intentional use of deception or manipulative tactics; the exercise of self-control in anticipation of greater rewards; the evaluation of one's position within a social hierarchy; the expression of emotions such as shame, guilt, or pride; and the strategic coordination of actions to influence others. These behaviors reflect an advanced level of internal reflection and a recognition of one's own existence and mental state.

On the other hand, the brain effectively utilizes ancestral contents as part of its computational processes. These contents, which include reflexes, instincts, and genetic predispositions, form part of a reservoir of biological memory that has developed throughout evolution. From the perspective of SK, these mechanisms can be understood as optimized computation of energy flows, structural mapping of critical pathways, and precise timing for survival and adaptation. This illustrates how SK concepts can be applied to a deeper understanding of how the brain and nervous system manage both inherited information and automatic adaptive responses.[92]

Congenital contents, also known as the "newborn's endowment," have been extensively documented and supported by scientific studies in various fields, including neuroscience, behavioral genetics, evolutionary biology, and cognitive psychology. This demonstrates how SK concepts can be applied to the profound understanding of how the brain and the mind process both congenital information and automatic adaptive responses

[92] Among the various psychological perspectives, these contents are referred to as the collective unconscious (psychoanalysis), reflexes, or adaptive responses (behaviorism and cognitivism).

(reflexes). Below are some examples of how these contents have been empirically validated:

- Innate Reflexes: Reflexes such as the sucking reflex in newborns, the Moro reflex (startle response), and the palmar and plantar grasp reflexes are automatic responses that have been consistently observed and documented across all human beings and other species. These reflexes are evolutionarily adaptive responses and are genetically programmed into the nervous system.
- Instincts, Emotions, and Inherent Behaviors: Behaviors such as fear of predators, the search for shelter, and attraction to certain stimuli are well documented across a variety of species, including humans. For example, fear of snakes or heights has been observed even in infants and other primates with no prior experience of those stimuli, suggesting an evolutionary and genetic basis for these responses.
- Genetic Predispositions and Behavioral Tendencies: Studies in behavioral genetics have shown that certain traits, such as shyness or boldness, can be inherited and are influenced by biological heredity. Experiments in mice, for instance, have demonstrated that certain genetic lines exhibit predispositions toward either more exploratory or more reserved behaviors, which result in differing responses to novel or threatening environments.
- Rapid Learning Mechanisms and Phobias: Specific human phobias, such as fear of heights (acrophobia) or snakes (ophidiophobia), are considered examples of rapid learning or biological predispositions with evolutionary foundations. This phenomenon is studied in evolutionary psychology and neuroscience, showing that the brain is prewired to acquire certain fears with minimal experience due to their relevance to survival.

Innate reflexes, instinctive behaviors, and genetic predispositions can be observed, measured, and studied across different species, including humans, which grants them a level of falsifiability and scientific validation.

On the other hand, when individuals feel that their choices or actions are being restricted or directed by others, this may lead to a sense of lost autonomy and authenticity, which, in turn, can reduce their vital energy and enthusiasm for life. Promoting intersystemic environments that respect autonomy and foster positive, supportive interactions can help preserve and enhance the energy of the conscious self.

Ultimately, the consequence of the configuration of this system is the capacity to reflect on one's own existence, with all its facets. From this starting point, and in parallel with the creation of so-called "mental maps," individuals proceed to make decisions and carry out the basic biological operations: computation, mapping, and timing.

We pause here to highlight some specific characteristics of this system:

- The self-aware system is sustained by the activity of specific neural networks, such as the dorsolateral prefrontal circuit, which plays a crucial role in decision-making and behavioral regulation. Neurogenesis, neuronal plasticity, or the ability of neural connections to adapt to new experiences, as well as mirror neurons and cognitive reserve (the brain's tolerance to physiological changes) allow the self-aware system to be refined and modified in response to stimuli from other systems of contact.
- Within the SK, the existence of the unconscious and its influence on thought, emotions, and behavior is acknowledged, in line with evidence from neuroscience and multiple psycho-

logical traditions.[93] However, unlike models such as classical psychoanalysis, which considers the unconscious a primary organizing force, the SK does not assign it a central or dominant role in the subject's architecture. Instead, the SK conceptualizes the unconscious as a basal and primitive system in terms of agency and directionality, characterized by an automatic flow of neural activity that can generate intense and unpredictable responses, particularly in emotional or high-stress contexts, as demonstrated by studies on amygdala activation. Its operations can be reinterpreted, shaped, and ultimately overcome through the strengthening of conscious thought, the construction of meaning, and relational affective synergy. Thus, the SK integrates its effects without resorting to a psychology of the hidden or an anthropology of determinism.[94]

- Self-awareness also depends on interaction with other systems. In embodied cognition theory, the body and sensory experiences influence how we perceive and organize our identity. This closely links the self-aware system to broader systems such as socio-relational systems.
- The self-aware system operates under principles of dynamic systems, where internal fluctuations (emotions,

[93] This perspective is supported by research demonstrating how automatic processes, such as cognitive biases or emotional responses, operate outside of awareness (Kahneman, Daniel. Thinking, Fast and Slow. Farrar, Straus and Giroux, 2011; Dehaene, Stanislas. Consciousness and the Brain: Deciphering How the Brain Codes Our Thoughts. Viking, 2014).

[94] In mammals, the unconscious manifests as a set of automatic neural networks underlying instincts, habits, emotional reactions, and internal dispositions. These networks are not always active but become deeply influential when triggered. Research on basic emotional systems in mammals, such as fear or seeking, supports this view, demonstrating how subcortical circuits operate automatically (Panksepp, Jaak. Affective Neuroscience: The Foundations of Human and Animal Emotions. Oxford University Press, 1998). The plasticity of these networks in mammals, evidenced in studies on learning and conditioning, suggests that even in animals, unconscious patterns can be modified, though to a lesser degree than in humans (Kandel, Eric R. 'The Molecular Biology of Memory Storage: A Dialogue Between Genes and Synapses.' Science, vol. 294, no. 5544, 2001, pp. 1030–1038).

thoughts) interact non-linearly with external stimuli, resulting in an adaptable but unpredictable system. This multicausality reflects the complexity of human decisions and the way individuals navigate between rationality and emotionality.

- The development of the self-aware system is also influenced by genetic and epigenetic factors. The activation or inhibition of certain genes, in response to experiences or external stimuli, can modify brain structure and, consequently, the way an individual experiences self-awareness and makes decisions.
- Emotional regulation, which includes the ability to manage emotions based on situations and social norms, is fundamental to rational decision-making. This interaction between emotion and reason is key to the configuration of the self-aware system, where emotional responses directly influence behaviors and perceptions.
- The self-aware system does not operate in isolation. Its interaction with the socio-relational system and the symbolic system, for instance, enables self-awareness to be shaped not only by internal phenomena but also by symbols and social norms that influence the individual's identity and behavior.

We emphasize that the SK provides an active approach to self-awareness. It is not merely a passive recognition of the "self," but a capacity to actively modify relationships with other systems through the optimized computation of energy flows and decision-making informed by temporal connectivity and structural mapping. This framework offers greater integration between self-management, emotional regulation, and adaptive mechanisms, highlighting how the self-aware system not only responds to other systems but also transforms them.

Human self-awareness enables individuals to understand their multidimensionality and multifrontality. To navigate this scenario, they must process large volumes of information in real time. Each dichotomous pair, such as beliefs and facts, desires and possibilities, tradition and rupture, introduces multiple streams of information that must be analyzed and weighed according to their relevance, urgency, and feasibility.

We have questioned whether this self-aware function warranted its own designation as a human microsystem. We believe it does not. It concerns gradients of complexity, refinements of a modality inherent to the animal condition. It is true that meta-observation is an emergent property of the self-aware "I" within the socio-relational system, particularly in humans. This capacity allows us to analyze our thought processes, assess how we make decisions, understand our emotions and their impact on our behavior, identify patterns that cause us difficulties, and recognize how our actions and ideas influence others and are influenced in return.

Socio-relational system

For the SK, the socio-relational system constitutes an essential level of human complexity, as it extends beyond the skin and incorporates intimate and personal relationships, such as family and close friends. These bonds form the first circle of reference and support, enabling the earliest meaningful interactions and shaping the emotional and social development of the individual. Bowlby and Ainsworth’s attachment theory demonstrates how these early connections influence the ability to form stable bonds throughout life, while Cooley’s looking-glass self theory and Mead’s symbolic interactionism show that identity is a relational process, in which the subject is defined through interaction with others.

Beyond the intimate circle, culture and social institutions emerge as dynamic structures that not only shape individual identity but also expand it through shared symbols, norms, and values. Geertz considers culture to be a system of meanings that guides perception and action, while Bourdieu argues that institutions reproduce habitus that shape behavior and social integration. In this sense, the socio-relational system provides a broader framework of identity and context, in which individuals are connected to history, traditions, and a particular worldview. The connection between the individual and the collective is not static, but mediated by the intergenerational transmission of knowledge and participation in social practices that provide continuity to societies.[95]

From the perspective of SK, the relational nature of identity corresponds to the bidirectionality of complex systems. The self-aware self, far from being a closed entity, is linked to other systems of contact through energy flows that regulate its interaction. This implies that socialization is not only a cognitive phenomenon but also an energetic and structural one. In SK terms, personal and collective relationships can be "mapped" and represented as nodes in a dynamic network, where some behave as hot nodes with high interconnectivity and others as cold nodes, with a lower degree of interaction. A cultural leader, for example, functions as a hot node, since their influence generates structural reconfigurations in the socio-relational

[95] Non-human animals also exhibit socio-relational behaviors that influence their survival, reproduction, and social structure. These behaviors include: hunting, caring for offspring, protection against predators, courtship, territorial defense, alliance formation, collaborative and altruistic actions, and play, among others. Research in ethology and comparative psychology continues to reveal the complexity of socio-relational interactions in the animal kingdom.

network, while an individual with less social participation would act as a cold node, with more localized interactions.

Adaptability is an essential component of this system, as interpersonal relationships and collective dynamics encompass key phenomena such as the exercise of power, the division of tasks, cooperation, education, knowledge transmission, and cultural development, all of which are fundamental to the continuity of societies. Luhmann argues that social systems self-organize through communication, while Morin suggests that social evolution responds to feedback and constant reorganization processes. The SK expands this perspective by integrating the dimension of temporal connectivity, noting that socio-relational networks are reconfigured according to energy fluctuations and structural stability. In this sense, institutions and cultural practices not only transmit information but also modulate social energy, either promoting or limiting changes in collective organization.

The socio-relational system not only enables social cohesion but also conditions individuals' perception and action. The philosophy of SK emphasizes that consciousness is not a purely individual phenomenon, but rather emerges from the interrelation between subjective identity and the socio-cultural structure. Collective memory, for example, is a clear illustration of how temporal connectivity shapes identity, as the past is constantly reinterpreted according to present needs. In this way, the relationship between the individual and the socio-relational system is not unidirectional: the individual configures society just as much as society shapes the individual. This ongoing interaction reinforces the idea that social systems are not fixed entities, but dynamic configurations that evolve through a combination of internal and external factors.

In conclusion, the socio-relational system is a manifestation of human complexity structured through dynamic and adaptive interactions. Its study from the perspective of SK makes it possible to incorporate energetic, spatial, and temporal dimensions, providing a framework that integrates individual identity with collective processes. By emphasizing the bidirectionality of relationships and the networked structure of human interactions, SK offers a perspective that transcends reductionist approaches and enables a deeper understanding of social complexity.[96]

This approach transcends a static view of the self and conceives it as a dynamic system shaped by multiple interactions. The notion of a fragmentary, bifrontal, and circular identity aligns seamlessly with the SK framework, as it avoids reductionism and acknowledges the coexistence of internal and external structures in constant transformation.

The bifrontality of the self implies a continuous tension between internal and external dimensions, between what is inherently one's own and what is shaped by the systems one inhabits. Circularity highlights the absence of a fixed identity, suggesting instead a set of evolving paths reconfigured through interactions with other systems.

In other words, the "plasticity" of this system enables it to modify its structural morphology to meet social and communal demands.[97] The SK, by understanding social behavior within a

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[96] Yuval Noah Harari explains that humans dominate the world due to their unique ability to cooperate in large numbers and with great flexibility, something not observed in other species. Unlike animals such as ants, which cooperate in rigid ways, or chimpanzees, which only cooperate within small, familiar groups, humans are able to work together in massive groups that include individuals they do not personally know. This capacity is closely linked to our symbolic ability to create and believe in shared fictions, such as laws, money, and nations, which enables large-scale cooperation.

[97] Psychological schools that emphasize the relational condition of human beings, such as constructivism and family systems theory, suggest that our identity is largely shaped through

socio-relational system, offers a framework to analyze the motives behind human conduct through an interconnected and multidimensional paradigm. Here we list some key motivators of social behavior:

- Attachment to caregiving figures: The emotional bond formed from around six months of age is the most significant attachment in infancy, as it shapes one's way of being in the world and relating to others, particularly in relationships that require intimacy. This bond plays a crucial role in the development of personality and self-esteem. The same can be said of various parenting styles, which also have a lasting impact on an individual's formation.
- Need for affection and approval: Affection and approval generate a flow of positive energy that strengthens connections and cohesion within social systems. Affection fosters the construction of identity within a context of belonging, thus contributing to the system's stability.
- Pursuit of pleasure: The search for pleasure is related to achieving a balance between energy expenditure and the attainment of well-being, optimizing the performance of the socio-relational system. This pursuit is not only individual; shared or collective pleasure, such as that experienced in communal activities or celebrations, reinforces interaction and enhances the sense of community.

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our interactions with others. These perspectives recognize the existence of "multiple selves," proposing that we adapt and respond flexibly to different systems and relationships. From a complex perspective, this is not necessarily incompatible with the notion of a unified and continuous self. Instead, it points toward a more fluid and dynamic understanding of identity, one that is constructed through the diversity of our social experiences. It is not our aim to side with one of these perspectives over the other, but rather to highlight the epistemological richness that would emerge from integrating them.

- Fulfillment of desires: Desires are understood as driving forces that, when fulfilled, contribute to the system's adaptability and growth. When shared within social networks, desires generate common goals that push the system toward new configurations and objectives.
- Overcoming fears: This process allows the system to transition toward greater resilience, as individuals or groups increase their capacity to face threats. It thereby strengthens their autonomy and ability to adapt to unforeseen circumstances.
- Search for balance: The need to find equilibrium between effort and rest, activity and reflection, is essential. A balanced system is more sustainable and less vulnerable to disruption.
- Curiosity and the pursuit of knowledge: This behavior is oriented toward acquiring information and exploring the unknown. Within the SK, curiosity is a key driver of innovation and system evolution, enabling exploration and adaptation to new realities.

Each of these social behavioral drivers strengthens the socio-relational system described by the SK, contributing to the complexity and resilience of human systems. The interaction of these factors produces emergent behaviors that are unpredictable and dynamic, yet consistent with the system's overall balance and adaptability.

There are theoretical approaches that emphasize the relational dimension of human beings, highlighting their openness and plasticity in interactions with other systems. These perspectives suggest that the human subject is neither a fixed nor monolithic entity, but rather a constellation of adaptive identities and roles that emerge in response to diverse contexts and relationships. Far from being constrained to a rigid or hegemonic self-image, this range of behaviors unfolds in a flexible and dynamic manner. In this regard, some psychological schools posit the existence of "multiple selves," a concept that reflects the diversity of responses and facets the subject can adopt when facing changing demands. From the SK standpoint, this vision must be integrated with the existence of a constant, structuring self, which performs computations, mappings, and temporal coordination from its own subjective decisions.

Due to the longstanding presence of institutions governing our social lives, humans tend to naturalize their existence and operations, which implies that we are affected by them in energetic terms and are often inclined to promote reforms aimed at modifying their structural morphology. Moreover, the heterogeneity of the system, deriving from its transversal nature, makes it possible to observe a wide range of organizational forms, from families to political parties, including intermediary institutions like neighborhood clubs. Consequently, the overlapping with other systemic expressions is inherent to its very existence.[98]

In complex social systems, certain variables may hinder the synergistic management and functioning of the system and its interactions, thereby affecting empowerment and subsistence. Furthermore, organizational structures may become crystallized, causing the system's efforts to be lost, that is, lacking dynamism and allowing certain components to become functionally and structurally amplified at the expense of others that, conse-

98 From the SK perspective, for example, artistic creation and political activity are very important subsystems. Art, as a complex subsystem, cannot be understood simply as an isolated work or creation. From the SK's point of view, the artistic process is an intersection of energy flows (creativity, emotions), structural morphologies (styles, techniques), and temporal connectivity (the influence of past and future works). Politics can also be analyzed through the SK, where multiple variables (economic, social, cultural) interact in a complex way to give rise to emergent behaviors. That is, power relations, public policies, and citizen perception interact not in a linear manner, but through a complex network of interactions.

quently, weaken and risk extinction. Certain dynamics can obstruct the efficiency and adaptability of these systems.

In social systems, emergent behaviors can be either beneficial (creating synergies and increasing the system's adaptability and resilience) or detrimental (leading to inefficiencies, rigidity, and potentially to dysfunction or collapse). "Energy blockers" can be interpreted as elements or dynamics within a system that hinder the effective flow of information, resources, or energy, resulting in inefficiencies and a lack of synergy.[99]

The phenomenon by which certain components of a system become amplified or strengthened at the expense of others is a key aspect of the dynamics of complex systems. This can lead to imbalances and vulnerabilities within the system. In an organization, for example, if certain departments accumulate resources and power, this can hinder collaboration and innovation. To address these challenges, it is crucial to promote adaptability and flexibility within complex systems. This might involve encouraging a diversity of approaches and solutions, facilitating communication and collaboration among different parts of the system, and remaining open to innovation and change. It also requires attentiveness to signs of rigidity or inefficiency and a willingness to reassess and reorganize structures and processes that no longer serve the overall well-being of the system.

[99] In the organizational context, the aforementioned dynamics may manifest as excessive bureaucracy, lack of communication between departments, or resistance to change. If the structures within a system become too rigid or crystallized, they can hinder adaptation and evolution, leading to a loss of dynamism and potentially to obsolescence or system collapse. In the social or business sphere, this might be observed in the persistence of outdated business models or organizational structures that fail to respond to changing market or societal conditions.

In the context of subject-to-subject logics, the unfolding of interactions generates events, actions, and positions that are subjective, highly contextual, and often difficult to predict. This challenges us to avoid fixed categories or predefined concepts that might reduce the complexity of the phenomenon, thereby hindering the emergence and understanding of intervening variables. Instead, it calls for developments that enable the construction of flexible and adaptive maps capable of capturing the richness of relationships in complex systems.

A key example of this complexity is the interaction between two motivations for social behavior: the desire to fulfill a personal dream or project, and the need for approval from the family group and other significant individuals. These two forces do not operate in isolation; in complex social systems, they interact and influence each other, giving rise to emergent responses that can redefine roles and behaviors.

The desire for personal fulfillment is an intrinsic motivation that drives the individual to pursue goals that reflect their own aspirations, values, and passions. It is an expression of the self-conscious identity, where the person seeks self-realization and personal satisfaction. On the other hand, the need for approval from the family group and other significant individuals represents an extrinsic motivation. It is related to the social relational self, as it involves the desire to be accepted, valued, and supported by those who play a meaningful role in the individual's life. This need can influence decisions and actions in order to align with the expectations and norms of the group.

The interaction between these two motivations can generate internal tensions and conflicts. For example, a person may have a professional dream that does not align with their family’s expectations. This internal conflict requires a process of negotiation and adaptation, both within the self and in relation to others.

Thus, the SK offers a rich perspective for understanding how personal motivations and drives intersect and amplify within relational systems. By studying these drives as dynamic flows of energy and meaning that traverse various structures and connection times, it becomes possible to better grasp the complexity and adaptability of human behavior within social frameworks.

From the SK's standpoint, the socio-relational system is a constantly transforming web, where energy flows, identity structures, and social interactions are configured in a dynamic equilibrium. There are practices, rituals, and institutions that, by shaping the structural morphology of this system, can be empowering, promoting the expansion of both individual and collective potential. Others, however, may be hegemonic and alienating, limiting the subject's freedom and stifling creative development.

The implications of this distinction are fundamental for understanding the dynamics of adaptation and evolution within societies. Bonds, groups, and institutions that foster the broadening of human capacities enable the creation of collective products that reinforce identity and social cohesion. In contrast, alienating structures halt synergy and innovation, generating rigidity and fragmentation. In this sense, the SK provides a lens through which we can assess which types of relationships and social structures are necessary to foster growth and adaptation in an increasingly complex world.

Lastly, the ability to interpret others' intentions, emotions, and thoughts is a significant advantage of humans. This skill, known as "theory of mind," is crucial for communication, cooperation, and social relationships. It allows individuals to anticipate and understand the reactions of others, facilitating the construction of complex bonds and adaptation across different societies. Although some animals exhibit behaviors indicating a basic understanding of others' intentions, humans have developed this ability to a much deeper and more sophisticated level, which has been essential for the development of cultures, social organization systems, and collective knowledge.

Mental system for the organization of behaviors and intangible products

The SK posits that mental phenomena are not merely epiphenomena of the brain or reducible products of neuronal activity. Rather, they are emergent energetic configurations with specific structural morphologies and temporal connectivities. It is important to clarify that this "mental energy" does not refer to an independent substance, but to a dynamic relational pattern that emerges from the interaction between structure, flow, and time. These adjustments allow for adaptability, intentionality, and the constant transformation of both the internal and external worlds.

Products such as memory, imagination, and self-awareness are not fixed entities, but dynamic energetic flows organized within -and beyond- the physiological and neurological structure of the organism. This approach aligns with Gerald Edelman's theory of neuronal group selection and with the concept of self-organization proposed by Stuart Kauffman, whereby the interaction between components gives rise to new and unpredictable properties. From the SK perspective, the mind is a complex emergent system that cannot be understood without considering its openness to multiple systems and scales.

The mental system for the organization of behaviors and intangible products emerges from the interaction between energy flows, structural morphologies, and temporal connectivities. This perspective not only allows for the description of phenomena such as thinking, decision-making, or idea generation, but also enables the understanding of self-awareness as a dynamic phenomenon. In this line of thought, it connects with Andy Clark's theory of the extended mind, which proposes that cognitive processes are not confined to the brain but extend through interaction with tools, symbols, and external systems. Likewise, neuroplasticity -as studied by Michael Merzenich- demonstrates that the brain is in constant reorganization in response to new experiences, supporting the idea of an adaptable and perpetually evolving mind.

This mental system exhibits emergent behaviors such as anticipation -which projects future scenarios based on prior patterns-, perceptual reorganization, the generation of intentionality, and emotional modulation. Memory is not merely passive storage, but a flexible energetic reconfiguration aligned with Karl Friston's free energy principle, where the brain operates as a predictive inferential machine. Perception, rather than being a passive process, is actively modulated through the interaction of internal flows and sensory stimuli. Emotions, far from being automatic impulses, are dynamic structures that optimize adaptation and decision-making in uncertain contexts.

The products of this system include both higher cognitive functions and more chaotic or dysregulated processes, thus avoiding idealizations. Obsessive ruminations, persistent distractions, or overwhelming emotional responses are also expressions of the mental system, as they result from energetic loops that affect structural connectivity. In this way, the SK does not exclude disorders but considers them part of the super-complex dynamics of the system.

Self-regulation appears on two levels: as a minimal condition for functional balance, and as an emergent capacity that enables individuals to adjust their behavior based on the interpretation of internal states and environmental stimuli. This dual role supports an expanded homeostasis that integrates emotions, self-awareness, and planning.

The mind also constructs internal models of the world, in which imagination and memory function as energetic simulators capable of reconfiguring experiences and anticipating possibilities. This system enables deliberate action, the symbolic evaluation of consequences, and conceptual abstraction, facilitating the construction of knowledge and the evolution of thought. In this sense, the mind is a highly symbiotic system, as illustrated by Douglas Hofstadter in his studies on self-awareness and emergence.

It is, however, crucial to distinguish between the mental system, the symbolic system, and the self-aware system. Subjectivity emerges at the interface between them: it cannot be reduced to the mind, nor exhausted by language or self-perception. For this reason, the SK proposes a combinatory architecture in which these systems co-participate in the configuration of the subject.

The human brain -considered in the SK as the most supercomplex object in the known universe- houses this ever-transforming mental system. Its functioning depends on interaction with multiple systems: biological, symbolic, socio-relational, and technological. It is not an isolated or fixed structure, but a dynamic network where perception, information processing, and the production of meaning converge.

From an evolutionary perspective, the mental system should not be interpreted as a linear progression toward an ideal. The SK warns against teleological readings: while one can observe a progression in complexity from bacteria to humans capable of symbolic abstraction, this process has been contingent, stochastic, and multidirectional.

Nor is the mental system a purely philosophical abstraction without material basis: self-aware activity is observable in structured energy reorganizations and can be correlated with studies in neuroimaging, computational modeling, or complex network analysis. These methods allow for the investigation of how mental systems reconfigure themselves in response to new stimuli, experiences, or learning.

Education, artificial intelligence, and psychotherapy find in this approach an innovative path for describing, intervening in, and expanding mental processes. Understanding the mind as a relational, interdependent, and transformative system enables the design of more integrated strategies for cognitive, emotional, and symbolic development, opening new avenues for the study of the human mind.[100]

As an example, both a scientific theory and a work of art are intangible products that emerge from the mental system in interaction with external systems. These products, in turn,

[100] While Giulio Tononi proposes the Integrated Information Theory (IIT) to measure consciousness in terms of information integration (Φ), the SK rejects fixed quantification of consciousness and conceives it as a dynamic and relational phenomenon, dependent on energy flows, structural morphology, and temporal connectivity. On the other hand, Bernard Baars' Global Workspace Theory (GWT) posits that consciousness is a workspace where information competes for widespread dissemination within the brain, whereas the SK not only considers the propagation of information, but also integrates the roles of energy and structure in the emergence of consciousness. Finally, John Hopfield introduces models of associative memory based on neural networks, which the SK expands by considering that memory is not only reconfigured at the neuronal level, but also through interaction with socio-relational, symbolic, and technological systems. Unlike these approaches, the SK proposes a multidimensional and combinatory model, which is not limited to neuroscience but allows for the study of complex systems across multiple scales and disciplines.

modify the environment, in culture, science, or aesthetic perception, and generate new feedback conditions that reconfigure the mind of the creator. From the perspective of the SK, these processes are not isolated events but rather cycles of increasing complexity in which thought, through its expression, transforms its own source.

Symbolic System

The symbolic system is a complex set of communicative and representational constructions, universally present, composed of signs, gestures, images, and other elements essential for the transmission and processing of information across species, particularly among higher mammals. These representations convey both ordinary and fundamental aspects of life, conceptualizing abstract elements of reality. In this sense, they act as catalysts for social and cultural life in community, facilitating the integration and communication of individuals within a shared space. It is deeply connected with the socio-relational system.

From the SK perspective, the symbolic system can be analyzed through the triad of energy, space, and time. This approach allows us to view symbolic systems as forms of energy linked to their power of influence and their capacity to consolidate or transform behaviors, attitudes, and beliefs. Space is configured through the number, distribution, and mapping of users, followers, adherents, and multipliers who interact around the same symbolic system. Time, on the other hand, is reflected in the duration of its presence and its capacity to endure as a medium of community cohesion and influence.[101]

[101] The concept of "symbolic phase shift" refers to the ability of symbols to change their position and relevance within a community, depending on shifting contexts, such as social crises or cultural movements that either revalue or displace them.

Symbolism is essential for the creation, understanding, and communication of human, social, and cultural expressions.[102] This system encompasses various forms, such as languages, writing, numbers, and mathematical operations, as well as artistic expressions, narratives, myths, and rituals.[103] Additionally, symbolism includes archetypes and identity figures that structure a sense of belonging and cohesion within communities.[104]

Critical thinking enables us to review and update our interpretations, generating symbolic systems that are more aligned with the challenges of the present. This prevents us from falling into dogmatism, fanaticism, or the perpetuation of beliefs that are no longer useful or that may even be harmful.

In the framework of SK, symbols are viewed as high-energy entities that, when flowing, generate collective meanings and emotions. These symbols not only respond to the current needs of the community but, through a feedback process, influence the energetic flows of their users and the construction of a sense of identity. This circular process reinforces the cohesion and continuity of the symbolic system, as the symbol, once established, energetically returns to the individual a sense of

[102] For example, in psychoanalysis, symbolism has historically been essential in exploring the human mind and behavior. Symbols found in dreams, language, and art are seen as manifestations of unconscious desires and conflicts. Similarly, metaphors have been used as tools for understanding psychoanalytic concepts.

[103] It is estimated that over 7,000 languages are currently spoken, and that there are more than 4,200 religions in the world. This number includes a wide range of belief systems, from major world religions to small spiritual traditions and local cults.

[104] Beliefs can be both symbolic and rational constructions. Symbolic beliefs are grounded in systems of meaning shared within a culture or social group. These beliefs are often rooted in traditions, rituals, myths, and symbols. Rational beliefs, on the other hand, are based on logical reasoning and empirical evidence. They are formed through observation, experimentation, and critical analysis. Science and the scientific method are key examples of how rational beliefs are formed and validated. It is important to note that the distinction is not always clear, and many beliefs may contain both symbolic and rational elements.

belonging, a sense of purpose, and a willingness to invest personal resources in sustaining and expanding the symbol.

Beliefs and desires are projective matrices constructed from need, longing, or cultural imposition. This means acknowledging that they do not emerge spontaneously or "purely," but are the result of interpretive energy flows that shape our mental, emotional, and behavioral structures. The SK emphasizes that the symbolic system has a concrete impact on the structural morphology of the subject -for example, through bodily habits or emotional dispositions- and on their temporal connectivity -the duration and form of their relationships, decisions, and life trajectories-. From the SK perspective, although these symbolic matrices are inevitable -since every subject needs maps to inhabit the world- they must not be assumed as absolute truths. Supercomplex thinking promotes a critical, combinatory, and integrative attitude, in which beliefs and desires are constantly revised, intertwined, and reconfigured in dialogue with other system dimensions (biological, technological, emotional, ecological, rational, relational). In short, the SK does not propose denying symbolic systems, but intervening in them. Not to flee from subjectivity, but neither to absolutize it.

Ultimately, the SK advocates for the integration of rational and emotional symbolics, overcoming, on one hand, reductionist rationalism, and on the other, emotivist credulity. The goal is to balance and draw the best from the symbolic constructions of each era and surpass them with more integrative symbolics. The SK proposes that more integrative symbolic systems must be flexible and adaptive, designed to facilitate the coexistence of multiple perspectives. These symbolics must avoid both dogmatism and extreme relativism, remaining in constant dialogue with scientific discoveries. Furthermore, they must guard against tendencies toward biases, such as confirmation bias, or practices that aim to control or manipulate followers through coercion or fear.

The symbolic system is highly adaptive, and its dynamism and resilience depend on its ability to remain relevant and effective in its communicative and cohesive function. The increasing complexity of these systems, driven by technological and linguistic development, demands greater energetic input for their maintenance, processing, and expansion. This gives rise to symbolic systems that continuously encompass and adapt meanings to respond to an ever-expanding range of situations and realities.

From the users' perspective, these systems offer positive energetic feedback by reinforcing both collective and individual identity. The symbols that are chosen, maintained, and shared by the community provide a sense of belonging and purpose in the lives of their bearers, motivating effort, resource investment, and willingness to make sacrifices. This dynamic ensures that symbolic systems continue to evolve in alignment with the changing needs of communities and, ultimately, contributes to the group's long-term survival and cohesion.

Ultimately, symbolic systems are generators and amplifiers of meaning. They are engines of community cohesion and transformation that, when intertwined with the flows of energy, space, and time, constitute a central aspect of the biological macrosystem and of human organization. Their complexity and adaptability are indicators of their importance within cultural and social structures, as they enable communities to evolve, consolidate, and sustain their values through increasingly complex and nuanced symbolic manifestations.

While it is true that symbols act as nodes interconnecting thoughts, emotions, and actions, it is essential to further explore the complexity of language and communicative processes as fundamental elements of this system.

Human language is not merely a code for transmitting information, but a complex, emergent, and dynamic system that articulates meanings and structures the symbolic reality of individuals and collectives. Language performs interactive functions that shape both individual understanding and the construction of collective meaning networks; it does not simply describe the world, but transforms it: by constructing metaphors, relationships, and concepts, it generates interpretative realities that influence human practices. Therefore, language must be understood as a key component in the evolution of social complexity, especially in contexts where interpretations shape collective decisions and perceptions of the environment.[105] Language should be regarded as an "evolutionary symbolic system" in which meanings emerge, combine, and shift over time and through interaction.

Metaphors play a fundamental role in this construction, as they not only express feelings or ideas, but also fulfill a crucial function in the shaping of symbolic realities. From the perspective of SK, metaphors act as high-energy-density nodes that condense complex meanings into precise images, thereby facilitating the connection between abstract dimensions and concrete experiences. By synthesizing multiple meanings into a single expression, metaphors not only communicate but also shape the understanding of complex phenomena, establishing

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[105] "Symbolic evolution" implies that the meanings associated with a symbol are not static, but rather transform over time based on their integration into new collective narratives or their reinterpretation in response to historical and cultural changes.

symbolic links that enhance cohesion and collective understanding.

Human communication is not a linear process of sender-receiver, but rather a network of symbolic interactions where meanings are continuously reinterpreted. Communicative complexity arises when multiple voices, contexts, and perspectives generate diverse, and often contradictory, interpretations. This implies that the act of communicating is not merely a transfer of data, but a co-construction of realities.

From the perspective of SK, recognizing this communicative complexity means acknowledging that the interpretation of concepts is neither universal nor fixed, but rather contextual and variable. This is especially relevant in academic, political, and social spheres, where discourse generates realities that condition human action and interaction. Language is not merely a means of expression, but a dynamic symbolic network that connects past experiences, current knowledge, and future projections. This network is in constant evolution, adapting to new realities and resignifying previously established concepts. According to SK, language must be regarded as a network of symbolic interdependencies, where each new node, be it a word, expression, or concept, reconfigures the entire set of meanings. [106]

The challenge lies in modeling how language generates, amplifies, or reduces the complexity of human interactions.

[106] The SK perspective on the complexity of language and communication resonates with various contemporary theoretical frameworks. From Edgar Morin's complex thought and the biology of cognition proposed by Maturana and Varela, to Habermas's theory of communicative action and Deleuze and Guattari's rhizomatic approach, the notion of language as an emergent and dynamic system has been explored across multiple disciplines. Similarly, thinkers such as Luhmann, Hall, Vygotsky, and Derrida emphasize the contingent, sociocultural, and polyphonic nature of language. On the other hand, Jacques Lacan's view of language as a symbolic structure that articulates meanings in a non-linear way provides a valuable perspective on how language constructs complex realities.

Symbolic systems must account not only for linguistic structure, but also for the pragmatic and relational contexts in which language comes to life and acquires meaning.

Technological System[107]

These systems are characterized by being human-made creations designed to meet specific demands -typically of a socioeconomic nature-. They consist of technological components (both digital and analog), engineering methodologies, and advanced programs that interact with various systems of contact in the pursuit of operating effectively and efficiently. Technological tools extend the physical, cognitive, and sensory capabilities of humans, enabling them to overcome biological limitations and achieve goals that would otherwise be inaccessible.[108] Generally, they have a positive impact on users, as they reduce individual energy expenditure by allowing machines, products of the system, to perform tasks that were previously carried out by users, were impossible for them to perform, or now benefit an entire community.

Historically, early hominids transformed flint stones and clubs into more sophisticated tools such as axes, hammers, and spears. This ability to create and use tools marked a significant

[107] Many object to the inclusion of the technological system within the biological macrosystem. While we acknowledge the fundamental differences in origin, composition, and purpose, technology is often developed as an extension of human biological capacities, from simple tools to complex information systems. For this reason, technological systems can be considered a manifestation of human biology, enhancing our physical and cognitive abilities and, therefore, forming part of the biological macrosystem.

[108] We do not consider that non-human animals develop "technology" in the strict sense; however, many animals use objects from their environment as tools, and in some cases, construct sophisticated structures. Nevertheless, it is important to distinguish between the instinctive or learned use of tools and structures in animals and the development of technology in humans, which involves complex processes of design, innovation, and abstraction. "Animal technology" is generally task-specific and does not exhibit the same cumulative innovation capacity that characterizes human technology.

milestone in their development, enabling them to hunt, defend themselves, and carry out various tasks more efficiently.

As they acquired more knowledge and skills, they began to experiment with different materials and techniques. They learned to carve and sharpen stones with greater precision, to use bones and antlers to craft more specialized tools, and to design utensils for specific tasks such as fishing, gathering food, and making clothing.

This increasing complexity in tool-making reflected not only technological advancement but also a significant cognitive development. Hominids began to plan ahead, understand the properties of materials, and pass on this knowledge across generations. The sophistication of tool technology was fundamental to their survival and evolutionary success, allowing them to adapt to diverse environments and improving their ability to secure resources.

By their nature, technological systems tend to progress alongside scientific advancements, which enable them to adapt to new needs, as the demand for constant updates and innovation is inherent to the existence of this type of system. As of today, although they remain human creations and are subject to human will, semi-automatic configurations and systems with self-learning and decision-making capabilities are proliferating, increasingly operating autonomously.

Moreover, these systems are unavoidable and indispensable for modern societies, which rely on them for both daily operations and long-term progress, encompassing everything from basic infrastructure to the provision of public services. In other words, the link between social life and technology is virtually total. Therefore, the survival of these systems is tied to the survival of humanity. Nonetheless, from an adaptive perspective and considering that every human creation is bound by the effective fulfillment of its original purpose, the continued existence of a particular technological system is ultimately conditioned by the emergence of another system that proves more efficient.

A) Techno-Engineering Subsystems

Techno-engineering systems integrate various elements of technology and engineering; generally, they consist of structures and machines designed to solve specific types of problems and are based on the use of technological advancements such as specialized devices and software. From the perspective of SK, these subsystems are understood as energetic nodes that amplify human capabilities, extending physical and cognitive limitations through energy flow processes that transform manual tasks into automated or semi-automated processes, optimizing the use of space and time.

These systems require energy provided by another system, humans (and in exceptional cases, other animals), which means they are, strictly speaking, human extensions created to manipulate reality and systems of contact. SK holds that these subsystems allow for the "externalization" of human capabilities, increasing the overall complexity of the system by integrating new capacities for adaptation and feedback that enhance its own evolution. In this sense, the configuration of such a system will depend on the human demands, of varying nature, it is intended to satisfy.

The adaptability and survival of the techno-engineering system, considered as an abstract representation of the collective, are guaranteed by its indispensability in the modern world. The absence of these systems in today’s societies is inconceivable. Moreover, the accelerating pace of technological advancement is bound to reconfigure existing models and drive the emergence of extraordinary new products, heralding a true technological revolution. This adaptability and constant capacity for innovation are understood as part of a process of temporal and spatial connectivity, in which the function of each system is determined by its relevance within a specific environment and time. This implies that as they evolve, techno-engineering systems not only respond to current needs but also contribute to the development of an environment that, in turn, poses new demands for complexity.

B) Cyber-Analog Subsystems

Cyber-analog subsystems are composed of both digital and analog elements and, like techno-engineering subsystems, are human creations. These are interconnected information and communication systems whose energy is based on self-learning and the enhancement of skills beyond those of other systems. These systems are designed to bridge the physical and digital worlds, aiming to improve the functionality and reliability of physical systems through digital computing and communication capabilities.

Typically, they are used to transform information obtained from reality, such as sound signals, into digital format for processing. Once processed, the previously digitized data is converted back into analog signals in order to control automation devices. Common examples include digital systems for information control and decision-making. In robotics, for instance, we find robots that use analog sensors to detect environmental inputs (such as distance or temperature) and digital control systems to process this information and make decisions.

From the perspective of the SK, this translation of information between the physical and the digital is not merely a transformation process, but a complexification of the system's energetic and informational flow. This adds what could be called an "energetic circularity," in which the system dynamically adapts and responds to its environmental conditions, thereby enhancing its capacity to operate across diverse contexts.

Unlike techno-engineering subsystems, the adaptability of cyber-analog systems is deeply linked to their capacity to process and adjust information in real time. The additional complexity introduced by self-learning systems allows them not only to respond to immediate demands, but also to anticipate and generate new solutions through internal reconfiguration and the creation of mapping behaviors. This property of adaptive self-expansion makes cyber-analog systems key components of the technological infrastructure within the SK, enhancing both their complexity and their capacity for intervention.

An interesting case to analyze is that of artificial neural networks (ANNs), as they model, in simplified form, the learning, adaptation, and information-processing mechanisms characteristic of biological systems. From the SK perspective, ANNs can be understood not only as tools for prediction or classification, but as functional representations of the complexity inherent in the human brain, a supercomplex system par excellence. In this sense, ANNs act as bridges between analog and digital systems. On one hand, their architecture emulates the continuous and adaptive properties of analog systems, enabling the transmission and transformation of signals across layers of interconnected nodes. On the other hand, they operate within digital environments, where their processes are discrete and computational.

Analog systems, as conceived by the SK, offer an enriching perspective for understanding the dynamic flow of energy and data within an artificial neural network (ANN). While digital systems operate with discrete units of information, analog systems focus on continuous relationships and gradients of change. This paradigm is crucial for modeling processes such as synaptic plasticity in neural networks, where interactions are not binary but gradual and context-dependent.

In summary, the connection between ANNs and the SK not only redefines our understanding of complex systems but also drives the development of more integral and adaptive technologies. These technologies, inspired by the synergy between the biological, the analog, and the digital, may offer innovative solutions in fields such as artificial intelligence, biomedicine, and robotics, aligning with the SK's integrative vision.

CHAPTER NINE

AN INTEGRAL AND INTEGRATIVE PERSPECTIVE ON BIOLOGICAL SYSTEMS

Biological systems are living examples of complexity, manifesting in dynamic interactions that span from the molecular level to entire ecosystems. SK not only enables the analysis of the intricate web of relationships in nature, but also connects these principles with social systems, highlighting how the human-nature interaction can be reconfigured to ensure sustainability and resilience.

In an increasingly interdependent world, addressing the multifaceted challenges of our time requires transdisciplinary frameworks. SK invites collaborative dialogue that promotes the harmonious coexistence of biological systems and adaptive societies capable of thriving in an ever-changing intersystemic context. This is why, from the perspective of SK, we consider:

a) Biological systems are interconnected through nonlinear networks of interaction that operate across various levels of complexity, where the pursuit of survival and well-being are fundamental objectives.[109] This is reflected in the principle of natural selection, in which organisms and behaviors that best adapt to their intersystemic environment have higher chances of survival and reproduction. SK distances itself from classical evolutionism at a crucial point: it is not the strongest or most

[109] We do not deny the importance of other objectives and behaviors such as cooperation, competition, genetic diversity, symbiotic interactions, culture, and social norms. We consider them as behaviors derived from these co-productions, sharing with them their corporeal-cerebral foundation. These intangible behaviors can also be found, albeit with less sophistication, in animals. Plants, in general, tend to generate more linear and innate behaviors, with a lower degree of system combinatorics.

linearly adapted who survive, but rather the system that most effectively manages the strategic interplay between energy, relationships, and temporality. The key lies not in brute strength or isolated endurance, but in the capacity to lucidly and intelligently combine three essential operations: computation (complex reading of flows and tensions), mapping (multiscalar representation of the system's relationships), and timing (temporal tuning of decisions). The systems that flourish are those that choose when to stabilize and when to emerge, when to sustain bonds and when to reorganize them, when to intervene and when to rest. Instead of passively adapting to their environment, they propose an active co-evolution with it. From this perspective, evolution is not a selection based on strength or speed, but on adaptive intelligence, strategic relationality, and conscious management of time and energy. These are the systems that become more resilient, creative, and sustainable, not because they avoid crises, but because they know how to transform them into opportunities for reorganization and strengthening. Complex biological systems, when interacting, not only activate latent potentialities but also generate emergent capacities that are refined through collaboration. This principle is exemplified in mutualistic dynamics, such as mycorrhizal networks that optimize nutrient absorption in plants through their interaction with specialized fungi, strengthening the productivity of terrestrial ecosystems.[110] At the microscopic level, the human microbiota illustrates how symbiotic microbial communities play a vital role in the immune and metabolic balance of the organism, becoming a cornerstone of personalized medicine by revealing direct links between its composition and

[110] Cfr. Smith, Sally E., and David J. Read. Mycorrhizal Symbiosis. 3rd ed., Academic Press, 2010.

the host's health.[111] Likewise, complex ecosystems such as coral reefs highlight emergent resilience arising from co-adaptive interactions among corals, fish, and microorganisms, allowing regeneration in the face of perturbations from other contact systems.[112] These interactions, operating simultaneously across multiple scales, find a conceptual parallel in systems biology, where complex networks are modeled to understand and anticipate adaptive dynamics. From the SK perspective, these phenomena are not merely described, they are transcended by anticipating strategies that integrate conservation, biotechnology, and health. In this sense, biological systems are approached through a lens that merges the individual and the collective, highlighting how nonlinear interactions generate a range of strategies for optimization, resilience, and survival, all characteristics of systems whose complexity depends not only on their structure, but on their capacity to relate.

b) Biological systems significantly influence other biological systems through various mechanisms, including physical, chemical, electromagnetic, and social interactions. These influences are fundamental to the dynamics of ecosystems, inter-organism relationships, and the biological processes occurring within individuals. One of the main mechanisms is the release of chemical substances, such as pheromones, allelopathic compounds, and the exchange of metabolites, which can alter the behavior, growth, or survival of other organisms. In addition, biological systems generate electric and magnetic fields through cellular activity, especially via processes such as action potentials in neurons and muscle contraction. Beyond these specific

[111] Cfr. Turnbaugh, Peter J., et al. "The Human Microbiome Project." Nature, vol. 449, no. 7164, 2007, pp.

[112] Cfr. Hughes, Terry P., et al. "Global Warming and Recurrent Mass Bleaching of Corals." Nature, vol. 543, no. 7645, 2017.

interactions, the ability of biological systems to influence others is essential for evolution, ecosystem balance, and the internal functioning of organisms. For instance, symbiotic relationships and trophic chains rely on these dynamics to ensure the stability and adaptability of biological communities. Understanding these complex interactions is key to various disciplines, including ecology, molecular biology, medicine, and behavioral sciences, as it enables a deeper understanding of how biological systems coexist, evolve, and adapt to their environments.

c) All complex biological systems are unique, yet they also belong to a species. An integrative and combinatory paradigm is essential for enabling equally in-depth description and intervention at both the individual and species level. For example, an alternative medical approach could address the particular characteristics of each individual without losing sight of the common traits of the species. This perspective would include a personalized evaluation of the patient, considering genetic, psychological, and social factors that influence their health, while also integrating knowledge and treatments based on species-wide patterns, such as typical responses to certain medications or epidemiological trends. This combined understanding and action would allow for the development of descriptions, predictions, and interventions that are valid on a large scale, without disregarding the possibility of tailoring treatments to each individual subject.

d) In all living beings, there is a multifunctional interaction between their subsystems and components. While some animals develop highly specialized functions, such as flight in bats or bioelectricity in eels, the human body stands out for the integration and optimization of its eleven systems. This enables it to perform an enormous diversity of tasks, ranging from physical activities to abstract processes like problem-solving or reflecting on one's own existence. In this way, the human body does not necessarily possess more systems, but it does have a unique capacity to transcend mere survival through the creation of culture, art, and science. Plants, on the other hand, also exemplify systemic interaction, albeit in a different way. Through photosynthesis, plants convert solar energy into chemical energy, which constitutes the energetic foundation of ecosystems. Their structural morphology is adapted to efficiently capture and distribute resources, while their processes, such as flowering or dormancy, are synchronized with natural rhythms. Thus, although their functions do not include abstract processes, plants play an essential role in the interconnection of living systems.

e) In biological systems, every act of communication, from an electrochemical signal to a social media algorithm, modifies the dynamic balance of the systems in interaction. This is because biological systems function as multiscalar complex networks, where information flows are not confined to a single level of organization. An electrochemical signal in the brain can trigger a series of adaptive responses that affect both internal processes (such as hormonal regulation) and external behaviors (such as social interaction). Similarly, a social media algorithm can alter patterns of group behavior by influencing perception and the exchange of information among individuals. In both cases, communication not only conveys information but also reconfigures prior relationships and balances, generating new systemic configurations.

f) Predation, this "eating each other", becomes a fundamental dynamic for the sustainability of nature, as it regulates populations, promotes biodiversity, and contributes to adaptive evolution. It is, indeed, a complex behavior involving multiple biological, ecological, and evolutionary factors, and although it may seem like a "cruel" game of survival, it sustains life cycles and enables the constant renewal of species. Unlike other animals, humans are capable of questioning and modulating our predatory behaviors, exploring ways to reduce harm to the biological macrosystem and to promote sustainable practices.

g) Deception, understood as a strategy for manipulating perception, plays a crucial role in both biological evolution and social dynamics. From the survival of organisms in nature to human interaction in complex contexts, deception emerges as an adaptive tool that provides specific advantages under certain conditions. In the animal kingdom, camouflage and mimicry are common forms of deception that allow organisms to protect themselves from predators or capture prey. For example, chameleons change their color to blend in with their environment, while orchids deceive bees by visually and olfactorily mimicking females of their species, thus facilitating pollination. Deceptive signaling is another evolutionary strategy. A notable example is that of false coral snakes, which mimic the color patterns of venomous species to deter predators by exploiting signals that typically indicate danger.In humans, deception takes more complex forms, such as withholding information, using makeup, or manipulating the truth. These strategies aim not only to gain individual protection or advantage but also to adapt to specific social norms or avoid conflict.

h) All biological systems, as we have already noted, are interconnected and interdependent, which requires that human developers act with care and responsibility in their interventions. The goal is to promote a dynamic balance that fosters diversity and resilience. This demands open-mindedness, as well as an interdisciplinary and transdisciplinary perspective in science and scientific practice. An example of this is ecology, where the elimination of a keystone species can trigger cascading effects in the food chain and ecological processes, underscoring the importance of considering the entire web of relationships when making decisions about conservation or management. Modern technology, such as biotechnology, genetic editing, and artificial intelligence, has revolutionized our interaction with biological systems, generating significant advances in health, reproduction, and longevity. These advances enable personalized medicine, the treatment of diseases, and the optimization of biological resources. However, they also present serious risks, such as uncontrolled genetic modification, which can disrupt ecosystems.

i) There are behaviors and intangible products co-produced by the systems of the self-conscious self, the socio-relational self, and the symbolic system that generate supercomplexity. These include thoughts, emotions, dreams, beliefs, imagination, creativity, values, ideologies, perceptions, and subjective experiences. This multiple and generally interwoven generation can give rise to conflicts and tensions. For example, emotions influence how we relate socially, affect our self-awareness, and shape our symbols and thoughts. This intertwining, though natural, can generate tensions that force the subject to carry out a higher-order mapping. The same occurs with social norms and expectations, which may clash with personal motivations and desires, as well as with personal identity which, depending on the different social roles we assume, may enter into conflict.[113]

[113] While brain chemistry facilitates processes of memory and learning, social and cultural experiences modify synaptic connections and chemical patterns over time (neuroplasticity). For the SK framework, consciousness, identity, and the interpretation of the other, for example, evolved as adaptive strategies, initially based on chemical mechanisms, but later

j) Another fundamental aspect is related to how biological systems manage the tension between well-being and survival. Often, strategies that maximize short-term survival may compromise long-term well-being, and vice versa. For example, an animal may need to consume a large amount of resources quickly to survive an immediate scarcity, but this could negatively impact its long-term health. In humans, this tension is reflected in everyday decisions: working long hours may ensure economic stability (survival) but harm mental and phy-sical health (well-being). For the SK, it is crucial to generate integrative strategies that address both aspects simultaneously. The search for solutions that promote both well-being and survival is essential for the sustainable development of biological systems.

k) Personal and social identity are the result of combinatorial learning and of the maps that individuals and societies create regarding which systems, and under what modes of interaction, will participate in the decision-making processes that sustain their survival and well-being. This highlights how culture, education, traditions, and beliefs influence both our decisions and the way we see ourselves and our relationship with the world.[114] Personal and social profiles can be descriptively constructed, in which certain systems occupy central positions, while others are articulated as dependent. The construction of these profiles, based on the centrality of certain systems over others, reflects that some structures or processes may be more dominant or influential in particular personalities or societies. In sociology, for example, it is analyzed how certain institutions or cultural norms shape individual and collective opportunities, as

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diversified and became more complex with the development of symbolic and social structures.

[114] A common regret among older individuals is having worried too much about others' expectations and opinions instead of having lived authentically.

well as perceptions and behaviors.[115] In education, mechanisms of conditioning, deception, and manipulation are analyzed. The integration of biological systems generates multiple benefits: living longer, enjoying greater well-being, and establishing enriching and empowering relationships. In humans, these benefits are enhanced through the production and enjoyment of culture, art, play, and technology.[116] In addition to integration, we may consider sophistication, which implies a high degree of refinement, skill, or complexity in the execution of these complex behaviors, due to the amount of information or abilities required to carry them out effectively. For example, bird migration is a complex behavior, as it requires coordination, communication, and advanced navigation skills. The same applies to artistic creation, sexual inclinations and practices, and scientific-technological research, among many other activities that express the creative potential of human beings.

l) The evolution of social structures leads to greater sophistication, ambivalence, and consequently, complexity in the behavior of both individuals and groups. As these structures become more complex, so do the dynamics of power, conflicts of interest, and forms of social interaction. This phenomenon is observable in various mammalian communities, where social

[115] A study conducted by Nisbett and Masuda in 2003 examined how culture influences visual perception. They found that individuals from Eastern cultures tend to pay more attention to context and the relationships between objects, whereas individuals from Western cultures tend to focus more on individual objects. Another study, conducted by Becker and Mulligan in 1997, found that individuals with higher levels of education tend to make more informed and long-term financial decisions, such as in retirement planning and investment. A third study, published in Social Science & Medicine in 2016, examined how cultural traditions influence health-related behaviors and outcomes, particularly the adherence to specific diets, such as the Mediterranean diet, or to traditional medical practices, such as Chinese medicine

[116] This perspective can be applied to human rights by emphasizing that the dignity of every human being is linked to the community and to the biological systems of contact and interaction. The interdependence promoted by the SK underscores the need to respect and guarantee the rights of all as part of an integral system

organization significantly influences the expression and management of violent and conflictive behaviors. On one hand, the evolution toward more complex social structures can reduce direct violence in certain areas by promoting norms, justice systems, and cooperative and altruistic behaviors that benefit both the individual and the group. These regulatory structures enable conflict resolution without resorting to physical violence, thereby strengthening social cohesion. On the other hand, these same complex social structures can give rise to more sophisticated forms of violence and conflict, both direct and indirect. Competition for power, resources, and status manifests in political, economic, and social conflicts that do not always result in physical violence but may lead to symbolic and structural violence. This type of conflict is expressed through inequalities and injustices embedded in institutions and social norms, perpetuating disparities in power and opportunity.

From the SK Community, we denounce the ideological and hegemonic use exercised by certain power groups that alter the dynamic equilibrium of systems for their own benefit. These asymmetric power positions tend to naturalize excessive control by imposing dogmas, slogans, and fanaticism through educational institutions and the media, enacting partial laws, manipulating the electorate, exercising invasive surveillance, and excessively exploiting natural resources. These strategies undermine the constructive role of the individual and of groups working toward the common good.

The result of such practices is the loss of personal freedom and desire, the increase of social conflict between supporters and critics of the prevailing model, the dominance of passion and fanaticism over rationality, and the rise of selfish and opportunistic attitudes over solidarity and collaboration.

Furthermore, these alienating forms of power management perpetuate inequality, classism, poverty, and colonialism.

For the SK Community, it is crucial to adopt an integral and integrative perspective to address contemporary challenges. These challenges are, by nature, interdisciplinary and transdisciplinary, and require a paradigm that takes into account the interaction and balance among all systems involved.

CHAPTER TEN

THE DYNAMIC BIDIRECTIONAL TRIPLE OVERLAP

The universe is as it is, not as we might wish it to be, and within it, there is no linear "arrow" of complexity. Stephen Jay Gould critiques the traditional view of evolution as a progression toward "higher" or more complex forms. Instead, he argues that evolution is a process of diversification occurring within the "full house" of life, with no predetermined direction toward increasing complexity.[117]

In line with this perspective, Supercomplex Knowledge (SK) introduces the concept of a dynamic, bidirectional triple overlap among the macrosystems: microparticles, macroscopic, and biological. These systems do not evolve independently nor do they follow a linear hierarchy; rather, they mutually influence each other within a network of continuous interactions. Each macrosystem not only impacts the others, but is also transformed by them, generating supercomplex behaviors as a result of their interrelations.

Instead of conceiving of these macrosystems as isolated entities, the SK proposes that their evolution and behavior are deeply intertwined, giving rise to an unprecedented level of supercomplexity. This approach replaces the notion of unidirectional progress with an emergent dynamic in which systems combine, reconfigure, and generate new behaviors without a predetermined final destination.

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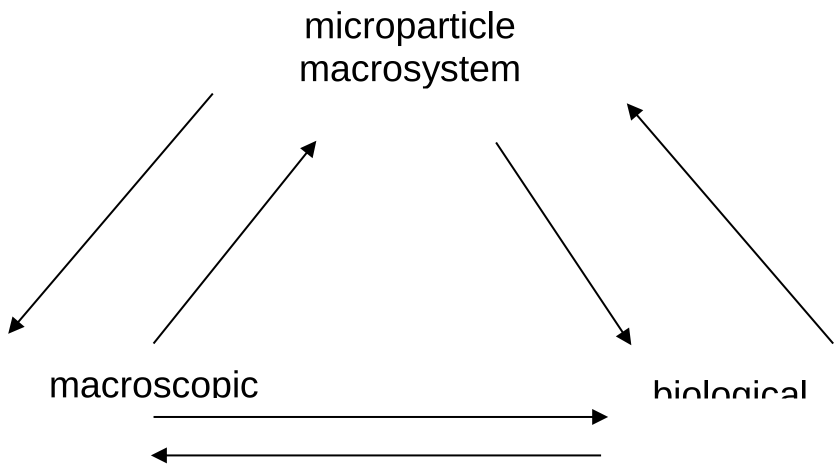
[117] This perspective challenges the mistaken idea of an inevitable linear drive toward greater complexity, suggesting instead that complexity arises as a possible outcome within a broader and more diverse spectrum of evolutionary paths. Gould employs statistical principles to illustrate that variations in complexity are determined by a range of factors rather than by a directed progression.

This development has compelled us to ask, among other questions: How does quantum mechanics influence the evolution of life? How do macroscopic structures impact the behavior of microparticles and of life itself? Can life modify the structure of the universe at fundamental scales?

In this chapter, we explore detailed examples of these interactions across various scales of reality, from subatomic particles to biological and physicochemical phenomena, and how these dynamic overlaps amplify complexity at both structural and energetic levels. For us, this process of bidirectional interaction represents the first level of supercomplexity.



MICRO OVER MACRO

1. The macrosystem of microparticles significantly influences the macroscopic macrosystem, as its fundamental properties are essential for understanding and predicting large-scale phenomena. The principles of quantum mechanics not only govern energetic interactions at the subatomic scale, but also play a crucial role in the early moments of the universe, shaping its evolution and contributing to the formation of cosmic structures. Quantum characteristics such as the Pauli exclusion principle and quantum entanglement determine essential physical properties of materials at large scales, including electrical conductivity, resistance, magnetism, and thermal capacity. Likewise, electronic configurations and chemical interactions between atoms and molecules, governed by quantum mechanics, make possible the formation of complex molecular structures and materials with specific functional properties. Another key phenomenon is quantum decoherence, through which a quantum system loses its intrinsically quantum properties when interacting with other systems, transitioning toward classical behavior. This process is essential for understanding how quantum laws, which prevail at extremely small scales, translate into the emergent and regular properties of the macroscopic world.

MACRO OVER MICRO

2. The macroscopic macrosystem can
exert a significant influence on the properties and behavior of quantum microparticles through various physical and chemical mechanisms. This influence is manifested in the way that macroscopic conditions impose constraints and determine the possible states of particles. Electromagnetic fields generated by macroscopic systems, such as magnets or electric currents, directly affect charged microparticles. These particles experience specific forces that alter their trajectory, velocity, and energy, thereby modifying their allowed quantum states. For example, in a spectroscopy experiment, large-scale controlled electric and magnetic fields determine the electronic transitions in individual atoms, limiting the accessible energy levels and facilitating the

observation of specific properties. Likewise, macroscopic conditions such as temperature and pressure are decisive in quantum behaviors. The thermal energy of a macroscopic system can excite quantum particles, promoting transitions between energy states. At low temperatures, on the other hand, unique phenomena are generated, such as the formation of Bose-Einstein condensates, where particles occupy the same quantum state, a phenomenon directly influenced by thermal effects. In the gravitational domain, macroscopic influence is especially relevant in astrophysical contexts. Microparticles moving in the vicinity of massive bodies such as stars or planets are affected by the curvature of spacetime, which alters their trajectories and quantum states. This gravitational effect can be critical in phenomena such as accretion disks around black holes, where subatomic particles experience drastic changes in their quantum behavior due to the intensity of the macroscopic gravitational field.

MICRO AND MACRO IN INTERACTION

3. There are complex phenomena that emerge from the interaction and feedback between the macrosystems of microparticles and the macroscopic. These phenomena arise when processes at the level of elementary particles influence large-scale behaviors, and vice versa. Notable among these are superconductivity, magnetism, and the Bose-Einstein condensate. Superconductivity is an emergent phenomenon observed when certain materials are cooled below a critical temperature, allowing electricity to be conducted without resistance and, therefore, without energy loss. This effect results from quantum interactions among electrons, causing them to behave as a collective state that overcomes ordinary dispersion. Another example is magnetism, especially in ferromagnetic materials such as iron. This phenomenon results from the alignment of the magnetic moments of electrons within atoms, which align in the same direction under certain conditions, generating a macroscopic magnetic field. Finally, the Bose-Einstein condensate is a state of matter that occurs near absolute zero. In this state, a group of atoms is cooled to extremely low temperatures and occupies the same space and quantum state, behaving as a collective 'matter wave' rather than as independent particles. These phenomena illustrate how interactions at the quantum level can give rise to emergent properties at the macroscopic scale, demonstrating the fundamental interdependence between microscopic and macroscopic systems.

THE MACRO UPON THE BIOLOGICAL

4. The influence of the macroscopic macrosystem on the biological is multifaceted and is fundamental for understanding the emergence of complex behaviors in life. These influences encompass a wide range of factors, from habitat conditions to interactions that profoundly affect the evolution and behavior of biological systems. Variations in climate, such as temperature, precipitation, and seasonality, significantly impact ecosystems, affecting both the distribution and behavior of species. These factors regulate life cycles and migratory behaviors, influencing the biological rhythms of various species. Macroscopic elements such as soil composition and the availability of nutrients directly influence the growth of vegetation and the fertility of habitats. Topography, mountain formation, rivers, and water availability are macroscopic factors that shape habitats and define the habitable areas for different species. Physical forces, especially gravity, influence the structural development of living organisms. Gravity, for example, conditions the skeletal and circulatory systems of animals and affects geotropism in plants, determining their orientation and growth in the terrestrial environment. Solar energy and other energy flows are essential for photosynthesis and food chains, sustaining life and biological complexity. Geological and climatic changes, such as continental drift, climate change, and catastrophic events (volcanoes, meteorites), have been important drivers of evolution.

THE BIOLOGICAL UPON THE MACRO

5. The biological macrosystem profoundly and multifacetedly influences the macroscopic macrosystem. Through key processes such as photosynthesis, respiration, nitrogen fixation, and decomposition, biological systems regulate the concentration and distribution of essential elements in the atmosphere, oceans, and soil, thereby modulating both the climate and the chemical composition of the planet. Ecosystems, particularly forests and oceans, act as carbon sinks, absorbing and storing CO_2, while deforestation and habitat degradation can release large amounts of carbon into the atmosphere, intensifying climate change. In addition, vegetation and biological interactions with the soil influence the formation and stability of soils, the prevention of erosion, and the regulation of the hydrological cycle, which impacts the flow and availability of water in the terrestrial environment. Plants, by modifying terrestrial solar radiation and participating in evapotranspiration, also affect temperature and precipitation patterns.

THE BIOLOGICAL AND THE MACRO IN INTERACTION

6. Interactions between the organic and the inorganic often involve complex feedback behaviors. For example, soils, which are essential for plant growth, are formed and maintained through the interplay of biological processes (such as the decomposition of organic matter by microorganisms) and inorganic processes (such as the weathering of rocks). The structure, composition, and fertility of soil are examples of emergent properties resulting from these complex interactions. The cycles of carbon, nitrogen, phosphorus, and other essential elements are regulated by the interaction of living organisms with other inorganic systems. The Earth's climate is influenced by biological processes, such as carbon sequestration by forests and oceans, and methane production by microorganisms in wetlands. Climate change, especially when influenced by human activities such as the burning of fossil fuels, is an example of how modifications in these processes can have complex global effects. Biodiversity and ecosystem structure are the result of millions of years of evolution, where the interaction between organisms and inorganic systems has given rise to a wide variety of life forms adapted to different ecological niches. The evolution of biodiversity is a complex process influenced by geology, climate, and other abiotic factors. These emergent complex behaviors demonstrate how life and inorganic processes are intrinsically intertwined, giving rise to the dynamic and self-organizing systems we observe in nature.

THE MICRO UPON THE BIO

7. The influence of the microparticle macrosystem on the biological macrosystem is a fascinating area of study that highlights the interconnectedness between the quantum and biological worlds. Although at first glance quantum phenomena may seem too small or isolated to affect biological systems, recent research suggests that quantum effects can, in fact, play a significant role in certain biological processes. For example, in the process of photosynthesis, it has been suggested that quantum coherence may play a role in the efficiency with which plants and certain microorganisms capture sunlight and convert it into chemical energy. Additionally, some enzymatic processes, which catalyze chemical reactions essential for life, may involve the phenomenon of quantum tunneling, where subatomic particles traverse seemingly insurmountable energy barriers. Furthermore, some animals, such as migratory birds and certain types of bacteria, have the ability to detect magnetic fields, aiding their navigation. Research has indicated that the phenomenon known as magnetoreception may involve quantum processes in specific molecules (cryptochromes) that react to magnetic fields, affecting the behavior of electrons in a way that can be perceived by the organism. Some researchers postulate that quantum tunneling, spin, and chirality are not only related to photosynthesis but also to protein synthesis, respiration, neuronal connections, and even mutations. Similarly, some DNA repair mechanisms may involve entangled quantum states, which allow repair enzymes to identify and correct errors in DNA structure with great precision, though this remains an emerging field of research. The ability of biological systems to harness quantum phenomena to efficiently carry out essential functions underscores the inherent complexity and adaptability of life.[118]

BIO ON MICRO

8. The question of whether changes in biological activities can influence quantum processes explores an emerging area of research at the interface between biology and quantum physics. Traditionally, it has been considered that quantum processes occur at very small scales and under specific conditions, such as extremely low temperatures or highly isolated systems. This makes it seem unlikely that biological processes, which occur at larger scales and under relatively "disordered" conditions, could directly influence quantum processes. However, recent research suggests that the situation may be more complex and nuanced, revealing unexpected interactions between the biological and the

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1. [118]Engel et al., 2007, published in Nature. The article, entitled "Evidence for wavelike energy transfer through quantum coherence in photosynthetic systems," presented evidence of wavelike energy transfer that can be explained by quantum coherence in the light-harvesting complexes of photosynthetic bacteria. This study suggests that quantum effects may play a role in the efficiency of photosynthesis.
2. Enzymatic Reactions and Quantum Tunneling. Study: Klinman, J.P. and Kohen, A., 2013, published in Chemical Reviews. The article, "Hydrogen Tunneling Links Protein Dynamics to Enzyme Catalysis," reviews how hydrogen quantum tunneling may be linked to protein dynamics in enzymatic catalysis, suggesting that quantum phenomena can influence the efficiency and specificity of enzymatic reactions.
3. Magnetoreception in Birds. Review: Hore, P.J. and Mouritsen, H., 2016, published in Annual Review of Biophysics. In "The Radical-Pair Mechanism of Magnetoreception," the authors discuss the radical-pair mechanism, a quantum process, as a possible explanation for how migratory birds can detect magnetic fields for navigation. It is suggested that certain quantum processes in light-sensitive molecules within birds' eyes may be involved in magnetoreception.
4. Olfaction and Quantum Mechanisms. Study: Franco, M.I., Turin, L., Mershin, A., and Skoulakis, E.M.C., 2011, published in Proceedings of the National Academy of Sciences. The article, "Molecular vibration-sensing component in Drosophila melanogaster olfaction," presents evidence suggesting that fruit flies are capable of discriminating isotopes based on their molecular vibrations, a phenomenon that could involve quantum mechanisms in the perception of smell.

quantum. For example, in the field of the physics of living systems and bioelectromagnetism, it has been observed that neuronal activity generates electric fields that, under certain conditions, could affect the orientation of electrons in nearby molecules, thereby altering their quantum properties. These effects may have implications for signal transmission and synaptic functioning in the brain, an area that remains an active subject of study. Another example of this interaction is the role of enzymes in essential chemical reactions. Enzymes can create specific microenvironments in which phenomena such as quantum tunneling, where subatomic particles traverse energy barriers, occur with greater probability. This phenomenon allows biological reactions to occur with an efficiency and speed that would be impossible without this mechanism and is crucial for processes such as photosynthesis and metabolism. Additionally, it has been proposed that certain biological molecules, such as cryptochromes in migratory birds, may influence subatomic particles by modifying the quantum state of electrons in response to magnetic fields. These changes in electron spin allow birds to detect magnetic directions, facilitating navigation during their long journeys. Other emerging studies suggest that quantum effects such as coherence and entanglement may be present in biological processes, especially in photosynthesis, where quantum coherence enables optimized energy transfer between photosynthetic complexes. It is also being investigated whether DNA repair mechanisms might involve entangled quantum states, helping enzymes to identify and correct errors with great precision. These examples reveal how biological systems may be modulating certain quantum effects, adapting environments that influence the behavior of subatomic particles to efficiently carry out essential functions. Research in this area offers a renewed perspective on the complexity and adaptability of living organisms, highlighting that life may be more deeply intertwined with the principles of quantum physics than previously thought.

BIO AND MICRO IN INTERACTION

9. Current technology uses DNA to modify microparticles in a variety of innovative applications, thus demonstrating how the biological-quantum interface contributes to the generation of complexity. This approach takes advantage of the unique properties of DNA, such as its ability to form specific and predictable structures through complementary base pairing, making it a versatile tool in nanotechnology and bioengineering. One notable application is the use of DNA to direct the assembly of microparticles into precise structures. By attaching complementary DNA sequences to different types of microparticles, these can be designed to self-assemble into specific patterns, creating structures with controlled and desired properties and functions. Furthermore, DNA-modified microparticles are employed to transport and release drugs in a controlled manner at specific sites within the body, increasing precision in therapeutic delivery. These techniques, which leverage the capacity of DNA to form complex molecular arrangements, provide a pathway for the development of personalized treatments and minimize side effects. DNA can also be used in the construction of microparticles that function as nanomachines or catalysts for specific chemical reactions. These programmable structures enable complex functions at the nano- and microscale, with applications ranging from precise chemical synthesis to cellular repair and the elimination of toxic substances. These applications demonstrate how DNA, beyond its central role in biology, is establishing itself as a powerful tool in nanotechnology and bioengineering, facilitating the creation of complex and functional systems at the intersection of the biological and the quantum. This use of DNA in the manipulation of microparticles opens new possibilities for the creation of intelligent devices and materials, with significant potential in medicine, materials science, and biotechnology.[119]

MICRO, MACRO, AND BIO IN INTERACTION

10. The interconnection between the micro, the macro, and the biological generates emergent phenomena in which the interaction between subatomic particles, physical structures, and living organisms gives rise to complex dynamics. One example of this interrelation is neurotransmission and its impact on behavior and society. At the level of microparticles, communication between neurons depends on electromagnetic and chemical processes, where the release of neurotransmitters such as dopamine and serotonin occurs through quantum interactions in the ion channels of the cell membrane. These signals propagate within neuronal networks in the brain, a macroscopic structure that regulates cognitive and emotional functions. At the biological level, the activity of these networks influences individual behavior, modulating mood, decision-making, and responses to environmental stimuli. However, the interrelationship does not stop at the organism; it expands to the social dimension: serotonin levels, for example, are involved in

[119] An interesting example is that of bioluminescence, an area of interest in which the interaction between biological and quantum processes may play a role. The emission of light by living organisms, in some cases, may involve the generation of photons through quantum-coherent chemical reactions. Research in this field could shed light on how biological systems achieve such feats at room temperature.

the regulation of aggressiveness and cooperation, influencing the stability of human groups and the structure of entire societies. Dopamine, on the other hand, plays a key role in reward and motivation circuits, impacting phenomena such as creativity, technological innovation, and economic organization. This convergence between the micro, the macro, and the bio shows how neuronal and chemical processes can translate into broad social behaviors, establishing a network of influences in which changes at one level can alter collective behavior.

In conclusion, we have shown how the dynamic bidirectional triple overlap is one of the cornerstones of this paradigm, demonstrating the way in which the macrosystems of microparticles, the macroscopic, and the biological affect each other in a constant and evolutionary cycle. Through these interactions, new forms of organization and behaviors are generated that amplify complexity (and supercomplexity), transforming our vision of reality from a linear and deterministic one to a stochastic and relational network.

CHAPTER ELEVEN

EQUATIONS OF COMPLEXITY AND SUPERCOMPLEXITY

Supercomplex Knowledge (SK) offers an integrative and transdisciplinary framework for modeling complex and supercomplex systems, drawing on advanced knowledge from physics, mathematics, and systems theory. Specifically, the incorporation of principles from quantum mechanics and advanced computational tools, such as quantum computing and machine learning algorithm, aims to innovate in system modeling. This approach not only aligns with cutting-edge proposals but also introduces novel methods to capture the nonlinear dynamics and multiscale interactions of systems.

SK makes a conscious effort to formalize the role of the observer, integrating perception and measurement directly into the dynamics of the modeled systems. This inclusion acknowledges that observation and intervention can alter the state of the system, an aspect often underestimated in traditional models. The mathematical modeling proposed by SK not only describes and predicts behaviors across multiple scales -from the microscopic to the macroscopic and biological- but also facilitates strategic intervention in these systems to guide their evolution in an informed manner.

This document is a preliminary and evolving work, subject to ongoing refinement and enrichment as research and experimentation within the SK Community advance. Collaborators and critics are invited to contribute to the development of this framework, ensuring it remains at the forefront of thought on complex systems

From the perspective of SK, it is crucial not only to employ differential equations but also to integrate advanced mathematical tools that reflect the nonlinearity and interdependence inherent in complex systems. Interactions between variables in such systems are neither uniform nor linear; therefore, robust mathematical models are needed to represent emergent dynamics and phenomena of self-organization. In this context, the use of nonlinear differential equations is essential to model the dynamic interactions among energy flows, variations in structural morphology, and changes in temporal connectivity. This approach is fundamental for uncovering hidden behaviors and bifurcations that may critically influence the evolution of the system.

The implementation of energy flow networks facilitates not only a structured and systematic visualization of system dynamics but also allows for a quantitative evaluation of its efficiency and stability. By adopting optimization principles in networks, similar to those proposed by Barabási in his analysis of complex networks, this method proves invaluable for identifying vulnerabilities or “bottlenecks” within systems where energy may accumulate or dissipate inefficiently. This technique is especially useful for intervening in biological and technological systems, where efficient energy management is crucial to maintaining system stability.

Furthermore, agent-based models, inspired by Holland’s work on complex adaptive systems, add significant analytical value by enabling simulations of both individual and collective interactions within the system. By integrating evolutionary parameters into agents, these models are capable of simulating adaptations in response to environmental changes, thereby capturing self-organizing processes essential to understanding the dynamics of supercomplex systems. The integration of machine learning algorithms with these models enables agents to adjust their behaviors based on prior experience, thus optimizing the system's evolution through adaptive feedback.[120]

On the other hand, complex network models go beyond merely capturing the structural interactions between components of a system; they also benefit significantly from advanced techniques such as centrality analysis and the evaluation of nodal relevance. These tools, which are pillars in network theory and have been extensively developed by experts like Newman, are crucial for identifying the most influential elements within a system in terms of connectivity and energy transfer. Through these analyses, it is possible to detect key nodes and connections that sustain the structural coherence of the system, an aspect that is vital for designing effective intervention strategies in biological, social, or technological systems.

Furthermore, advanced data analysis methods play a complementary and indispensable role in this modeling. Techniques such as data mining and complex network analysis can uncover emergent behaviors that would be imperceptible through simple direct observation. Inspired by the pioneering work in complexity science by figures like Prigogine and Kauffman, the recognition of complex correlations between energy flows, structural transformations, and temporal variations provides a robust statistical framework for model validation and the precise calibration of parameters.

Finally, in order to achieve a truly integrated perspective, the SK adopts a combinatory approach that harmonizes diffe-

[120] A concrete example could be the modeling of energy ecologies in marine ecosystems, where nonlinear equations describe how variations in water temperature affect trophic networks and biomass.

rential equations, network models, data analysis, and agent-based simulations. This unified mathematical platform enables a comprehensive understanding of complex systems, where each tool contributes a unique perspective that not only enriches the interpretation of energy flows, structural morphology, and temporal connectivity, but also feeds back into the analytical process itself. In this way, the SK strives to develop an adaptive and evolutionary model that not only describes the dynamics of systems but also provides effective strategies for their prediction and transformation.

THE EQUATION OF COMPLEXITY

The SK framework acknowledges the need for a rigorous mathematical formalization to present its theoretical proposal effectively. We have developed an equation that captures the interdependence between energy, spatial structure, and temporal connectivity in complex systems, fundamental elements for understanding their integral dynamics.

We argue that the flow of energy in a complex system is influenced not only by changes in structural morphology -that is, the shape and organization of the system- but also by temporal connectivity, which includes the duration and dynamics of internal interactions. Inspired by the pioneering work on dynamic systems by Prigogine and the network theory of Barabási, we propose a mathematical relationship in which the change in energy flow results from a multiplicative interaction between these factors, modulated by specific coefficients and exponents that reflect the complexity of their interactions.

Component Definition Key

1. **Energy Flow (EF):** Defined as the rate at which energy is transferred or transformed within the system, this component is measured in units of power such as watts (W). EF is essential for understanding how energy flows through and is utilized by the system.
2. **Structural Morphology (SM):** Represents a quantification of the system's spatial configuration. Depending on the context, this may include parameters such as surface area, volume, characteristic length, or fractal dimension. Alternatively, it may be defined using topological or geometric metrics, such as the number of nodes or the distribution of connections, offering a detailed view of the system's physical structure.
3. **Temporal Connectivity (TC):** Measures how interactions among the system's components evolve and change over time. This can be expressed in terms such as the average duration of connections, interaction frequency, or indices of temporal persistence. It can be quantified in units like seconds, Hertz (frequency), or dimensionlessly if normalized.

In this way, the first, still primitive expression would be:

$$\Delta EF = \Delta SM \times \Delta TC$$

- **ΔEF:** Change in the system's energy flow, that is, the variation in energy flow relative to a reference or initial state.
- **ΔSM:** Change in structural morphology.
- **ΔTC:** Change in temporal connectivity.

This initial equation expresses the variation in energy flow as the product of the variation in structural morphology and temporal connectivity.

It represents a starting point for understanding the dynamics of complex systems through the components EF (Energy Flow), SM (Structural Morphology), and TC (Temporal Connectivity), which are central to the SK. However, this basic formulation assumes a direct and linear relationship between these three components, without considering how the spatial and temporal evolution of structural morphology and temporal connectivity affect the system's energy across different scales. Its simplicity allows for the establishment of a basic analytical framework, but it limits its ability to capture emergent behaviors, fluctuations, feedback loops, and spatial heterogeneities that characterize complex systems.

To overcome these limitations, it is necessary to introduce a more general formulation that incorporates spatiotemporal variability, nonlinearity, and the possibility of scaling across systems of different magnitudes.

The proposed equation to describe the dynamics of complex systems is the following:

$$\frac{dEF}{dt} = k \times \int_{\Omega} \left(\frac{dSM(t,x)}{dt} . \frac{dTC(t,x)}{dt}\right)^{\gamma} \left(\frac{SM}{SM_{0}}\right)^{\alpha} \left(\frac{TC}{TC_0}\right)^{\beta} dx + \eta(t, x)$$

The equation describes how energy flow evolves over time based on the interaction between structure and temporal connectivity. These two factors not only determine the distribution and transformation of energy within the system, but also regulate its stability and adaptive capacity. Their interaction generates complex dynamics that can give rise to emergent behaviors and changes in the system's organization.

The inherent variability in complex systems does not manifest in a uniform or linear way, as their behavior results from multiple factors interacting unpredictably. The inclusion of the exponent γ in our mathematical model introduces significant nonlinear effects, allowing small variations in structure or connectivity to have amplified or attenuated impacts, depending on the specific value of γ. This highlights the system's sensitivity to initial conditions or minor changes, underscoring the importance of understanding these dynamics in order to predict and manage the system's evolution.

The coefficients α and β, on the other hand, modulate the relative influence of structural morphology and temporal connectivity, respectively. These parameters are crucial for determining how these components affect energy flow across different scales, providing a mechanism to fine-tune the model according to the specific needs of the system under analysis. Additionally, the inclusion of the stochastic term $\eta(t,x)$ introduces an element of uncertainty into the model, capturing the influence of internal random fluctuations and external factors that may unexpectedly alter the system's trajectory.

One of the key strengths of this model is its scalability and its independence from specific units, thanks to the use of dimensionless factors. This feature allows the model to adapt to systems of various natures, from small neural networks to large ecosystems, without compromising its mathematical or conceptual coherence. The model is particularly useful for examining phase transitions in systems, where the combination of structural morphology and temporal connectivity can reach critical thresholds, triggering abrupt reorganizations and establishing new energetic equilibria.

The model enables simulations of how alterations in neural networks affect the propagation of electrical activity in the brain, supporting research on synaptic plasticity and learning processes. It could be used to assess how biodiversity and ecosystem structure influence energy flows among species, which is essential for studies on ecosystem resilience and stability. Additionally, it provides a framework for analyzing information propagation in dynamic networks, allowing for the study of how temporal interactions affect the diffusion of ideas and resources. Finally, it is applicable in the study of self-organizing processes where spatial and temporal interactions determine the system's evolution, offering a basis for describing emergent phenomena at different levels of complexity.[121]

Ultimately, the adoption and promotion of the SK mathematical model drives the forefront of research and development and enhances an organization’s strategic capacity to anticipate and adapt to change, manage resources effectively, and explore new opportunities.

THE EQUATION OF SUPERCOMPLEXITY

The Equation of Supercomplexity emerges as a response to the need for a mathematical formalization of concepts that, until now, have been explored mainly within the philosophical domain. While an equation has already been formulated to address complexity, it is equally crucial to develop one specific to supercomplexity, one that captures the overlaps between macrosystems, the cognitive and constructive activity of the observer, and the impact of observation and measurement tools. Without such formalization, the concept would remain relegated

[121] The model introduces stochastic terms and coefficients that allow for the modeling of uncertainty and random fluctuations, crucial features for planning in rapidly evolving and uncertain environments. The ability to anticipate and adapt to abrupt changes or phase transitions can be a decisive factor in operational and strategic risk management. The model can be implemented in simulation and forecasting systems to improve risk management in critical operations, especially in sectors such as energy and finance. Since the model has applications across multiple disciplines, it presents an excellent opportunity for interdisciplinary collaborations that can open up new areas of research and development. These collaborations may lead to disruptive innovations and the creation of new markets.

to mere theory, lacking practical applications for the analysis and modeling of intricately interconnected systems.

The overlap between macrosystems can be represented by a coefficient that measures the intensity and nature of the interactions among them, capturing how complex systems interpenetrate and mutually influence one another. The observer's activity must be incorporated as a key factor, since their perception, interpretation, and construction of reality directly affect how systems are studied and understood. This component not only measures the impact of the observer on the perception of the system but also introduces an active dimension, where the cognitive subject intervenes in and modifies their object of study. Observation and measurement instruments constitute another fundamental variable, as they determine the precision, scope, and depth with which a system can be analyzed. These tools expand available knowledge by enabling the detection of phenomena that would otherwise remain inaccessible. However, they also introduce limitations and biases, depending on their capacity and resolution.

The proposed equation for supercomplexity is the following:

$$\frac{dS}{dt} = k \times \int_{\Omega} \left(\frac{dSM(t,x)}{dt} . \frac{dTC(t,x)}{dt}\right)^{\gamma} \left(\frac{SM}{SM_{0}}\right)^{\alpha} \left(\frac{TC}{TC_{0}}\right)^{\beta} dx \times O \times C \times I + \eta(t,x)$$

The equation of supercomplexity introduces new elements that expand the understanding of the dynamics of complex systems by incorporating the role of the observer, the coefficient of overlap between macrosystems, and the influence of measurement instruments. These factors allow us to model the relationship between systems and those who study them, showing how observation and intervention affect the system's evolution over time. Unlike the equation of complexity, which focuses on the interaction between structural morphology, temporal connectivity, and energy flows, the supercomplexity equation recognizes that no system can be studied without considering the impact of the knowing subject and the tools used to access information.

The observer, represented by the term O, is a key component in the equation, as their perception, interpretation, and theoretical framework affect how the system is modeled and understood. In supercomplexity, it is not assumed that knowledge is absolute or independent of the subject studying it; rather, it acknowledges that all observation is a construction influenced by expectations, intentionality, and the observer's ability to distinguish different behaviors within the system. When the value of O is high, it means that the observer’s activity significantly influences the dynamics of the system, which may manifest in changes in data interpretation or in interventions that alter the system’s very structure. Conversely, when O is low, the system evolves with less dependence on the analyst's activity, reflecting a greater autonomy of its internal dynamics.

The coefficient of overlap between macrosystems, denoted as C, measures the intensity of interconnection between the various systems interacting within a supercomplex environment. In the universe, systems do not exist in isolation; instead, they are in constant interaction and overlap, generating structures that depend on multiple levels of organization. This coefficient quantifies the extent to which systems affect one another, particularly relevant when modeling phenomena where different scales influence each other. When C is high, it indicates deeply entangled interactions between systems, such that changes at one level can trigger effects in others. An example of this is the relationship between neuronal activity, cognition, and social dynamics, where processes occurring at a microscopic scale can have repercussions in larger organizational systems. If C is low, the overlap is reduced, suggesting weaker cross-scale effects and relatively independent dynamics.

Measurement and modeling instruments, represented by I, play a decisive role in the construction of knowledge within supercomplexity. All observation occurs through tools that condition access to information and determine the level of detail and precision with which a system can be analyzed. A high value of I indicates powerful instruments that expand knowledge of the system, allowing phenomena to be recorded with greater accuracy and depth. Conversely, when I is low, the observational capacity is limited, which may lead to biased interpretations.

The incorporation of these terms into the equation of supercomplexity allows for the mathematical formalization of the relationship between the system under study and the process of knowledge construction. It models not only the system's evolution in terms of its structure and connectivity, but also the influence of those who observe it and the tools through which its dynamics are accessed. This shifts the modeling approach away from a deterministic view that assumes the existence of objective, observation-independent knowledge, and toward a perspective in which reality is not an absolute given, but a construction emerging from the interaction between the system, the observer, and the methods used to study it.

In contrast to the equation of complexity, which focuses primarily on the interactions between morphology, temporal structural connectivity, and energy flows, the equation of supercomplexity emphasizes that no system can be fully understood without accounting for the integral influence of the cognitive subject and the instruments employed to access information. This approach not only deepens the description of supercomplex systems, but also reinforces the need for a methodology that is both reflexive and expansive in its scope.

QUANTUM COMPLEXITY AND SUPERCOMPLEXITY

The incorporation of quantum computing within the framework of SK requires mathematical reformulations that leverage core quantum principles such as superposition, entanglement, and probabilistic evolution. What follows are the key modifications to the equations of complexity and supercomplexity, with the aim of describing systems with greater accuracy and computational efficiency.[122]

In this development, the foundational principles of SK are translated into the formalism of quantum mechanics. SK defines complexity as the result of the interaction between three components: energy flows (EF), structural morphology (SM), and temporal connectivity (TC). In the quantum version, these components are represented by operators (such as Ĥ_SM and Ĥ_TC) that act upon wave functions (Ψ), which represent the system's states in superposition and continuous evolution. The resulting formulation no longer describes deterministic values, but instead dynamic probability distributions, where the states of the system can collapse or reconfigure in response to the intervention of an observer, an instrument, or an overlapping system. Thus, while SK preserves its foundational three-dimensional structure (EF, SM, TC), it reinterprets them through the lens of quantum logic, which allows for multiple coexisting

[122] As previously stated, this presentation and its corresponding formulas are provisional and illustrative in nature. What is presented here is a working draft that is being constantly refined and improved.

states, state collapses, stochastic noise, and emergent transformations.

In a quantum version, we must replace the classical description of differential variations and scalar products with a matrix and operator-based representation, using the formalism of quantum mechanics.

The modified equation would be:

$$\hat{H}\Psi = i\hbar\frac{\partial}{\partial t}\Psi$$

Where:

- Ĥ is the Hamiltonian of the system, which now includes terms dependent on structural morphology and temporal connectivity.
- Ψ is the quantum wave function of complexity, describing the probabilistic evolution of the system.
- iħ ∂Ψ/∂t models the temporal evolution of complexity in terms of superposed quantum states.

The quantum noise term ηq(t, x) represents the probabilistic fluctuations inherent to the evolution of a supercomplex system. Unlike classical approaches, where noise is modeled as Gaussian perturbation or white noise, in SK this term can incorporate emergent fluctuations arising from system overlap, observer intervention, or the system's own internal disorder. This approach introduces a kind of "relational noise," which not only perturbs, but reconfigures the dynamics based on contextual interactions. Expanding this formalism in terms of SK, the quantum equation of complexity would be written as:

$$\hat{H}\Psi(EF,SM,TC) = k \times \int_{\Omega} (\widehat{SM}.T\hat{C})^{\gamma} dx + \eta_q(t,x)$$

Where:

- Ĥ_SM and Ĥ_TC are quantum operators associated with structural morphology and temporal connectivity.
- η_q(t, x) is a quantum noise term that introduces probabilistic fluctuations into the system's evolution.
- The integral over the space Ω is retained but is now evaluated in terms of quantum probability distributions instead of deterministic values.

This modification allows complexity to no longer be a fixed quantity, but rather a quantum state with multiple superposed possibilities, evolving according to principles of interference and entanglement.

On the other hand, the equation of supercomplexity, in its classical version, incorporates the role of the observer, instruments, and the overlap between macrosystems. If we consider that supercomplexity is a state that depends on the interaction between the system and the observer, we must reformulate the equation using wave function collapse and quantum measurements. The improved equation would be:

$$\hat{H}_S \Psi(S) = i\underline{h} \frac{\partial}{\partial t} \Psi(S)$$

Where:

- Ĥ_S is the Hamiltonian of supercomplexity, which now includes the action of the observer and the measurement instruments.
- Ψ(S) represents a quantum state of supercomplexity, which may collapse into different values depending on the measurement.
- iħ ∂Ψ(S)/∂t describes the probabilistic evolution of supercomplexity over time.

Expanding this formulation:

$$\hat{H}_S \Psi(S) = k \times \int_{\Omega} (S\hat{M}.\widehat{TC})^{\gamma} dx \times \hat{O} \times \hat{C} + \hat{I} + \eta_q(t,x)$$

Where:

- Ĥ_O and Ĥ_C are quantum operators modeling the impact of the observer and the overlapping of systems.
- Ĥ_I represents the influence of measurement instruments as quantum operators.
- The quantum stochastic term η_q(t, x) introduces random variability into the system's evolution.[123]

The quantum approach of SK finds parallels with various advanced theories in physics, neuroscience, and complex systems. Key studies and authors in these areas include:

- Roger Penrose: His work in The Emperor's New Mind and Shadows of the Mind suggests that consciousness may be based on quantum processes in neuronal microtubules, which resonates with the SK perspective on the interaction between the observer and the structure of the system.
- Stuart Kauffman: In The Origins of Order, Kauffman models self-organization in biological systems using Boolean networks and nonlinear dynamics, a framework that can be extended through quantum computation within SK.
- David Deutsch: In The Fabric of Reality, Deutsch presents quantum computation as a superior way of processing information, which aligns with the potential application of SK software to model state superpositions in the evolution of supercomplex systems.

[123] In SK, the collapse of the wave function is not interpreted as the final determination of a state, but rather as an act of structural reconfiguration of the system, conditioned by new interactions, relationships, or boundary conditions. Collapse is not closure, but transition: a temporal, morphological, and energetic reordering based on the overlapping of complex systems.

- Seth Lloyd: In Programming the Universe, Lloyd proposes that the universe functions as a quantum computer, reinforcing the SK idea that the evolution of supercomplex systems can be modeled using quantum operators.

This presentation enables us to capture supercomplexity as a quantum state in evolution, where the observer, the overlap of systems, and the measuring instruments influence the structure of the system. Integrating quantum computing with our software (currently under development) would allow us to simulate these effects with greater precision and represent multiple possible configurations of systems in real time. Moreover, the combination of these models with advanced mathematical and physical approaches strengthens the innovative character of SK, allowing it to go beyond conventional descriptions of complexity and move into a framework where supercomplexity can not only be understood, but also manipulated and simulated using cutting-edge tools.

THE INCLUSION OF SPECULARITY AND MULTI-APPEARANCE

As we will see later, we define the process of institutional and business transformation as specular (seeing oneself in a mirror) and respectful of multi-appearance (the different perspectives held by all actors involved in the system). Do these equations allow for the inclusion of the qualitative?

The inclusion of specularity and multi-appearance in institutional and business systems enables the modeling of how actors perceive the transformation of such systems. This approach considers that the evolution of an organization is not only a structural change, but also a reconfiguration of internal and external perceptions. To achieve this, it is necessary to incorporate a specular perception function Ri(t), which represents how a node perceives its own influence as reflected in the other nodes of the system. This function allows us to model the node's self-image in relation to how it is perceived by others, generating a layer of subjectivity within the supercomplex transformation of the system.[124]

Each node, by modifying its behavior based on how it is perceived, introduces perceptual feedback that adjusts its structural morphology and temporal connectivity. In this way, systems change not only in an objective manner but also as a function of how they are interpreted. The coexistence of multiple perspectives within the system allows for modeling a reality in which actors adjust their decisions according to their self-image and the image perceived by others. To incorporate this perception matrix Pij(t) into the supercomplexity equation, it is necessary to define the relationship between each node and the perceptions that other nodes have about it at a given moment t.[125]

The term Pij(t) represents how a node believes it is perceived by another node within the system. In contrast, Pii(t) is the self-perception of node i, that is, how it sees itself in the system. When Pij(t) is not equal to Pii(t), a perceptual imbalance arises that can trigger adjustments in structural morphology and

[124] The inclusion of the specular perception Ri(t) and the perception matrix Pij(t) allows for the integration of qualitative aspects, such as the subjective perceptions of the actors, into a quantitative model. This is crucial because, in social and organizational systems, subjective perceptions and interactions are often just as influential as objective structural changes. By incorporating these dimensions, the equation more accurately captures the inherent complexity of such systems.

[125] Previous studies have explored the relationship between perception and organizational transformation within the field of complexity. Research in organizational psychology has shown that an institution's self-image influences its capacity for adaptation and resilience. In the field of systems sociology, Luhmann analyzed the role of perceptions in the self-reproduction of organizational systems, highlighting their impact on the evolution of social structures. Meanwhile, studies in strategic management have emphasized the importance of subjective interpretation in decision-making and in the dynamics of organizational transformation. These investigations reinforce the notion that perception is not only a central element in the evolution of complex systems, but that its integration into formal models can enhance understanding and intervention in business, community, and institutional contexts.

temporal connectivity.In this way, the corrected supercomplexity equation that includes specular perception and multiappearance is formulated as follows:

$$\frac{dS}{dt} = k \times \int_{\Omega}\left(\frac{dSM(t,x)}{dt} \cdot \frac{dTC(t,x)}{dt}\right)^{\gamma}\left(\frac{SM}{SM_0}\right)^{\alpha}\left(\frac{TC}{TC_0}\right)^{\beta} dx \times O \times C + \sum_i \sum_j P_{ij}(t)\left(P_{ii}(t) - P_{ij}(t)\right) + I + \eta(t,x)$$

Where $\sum\_i \sum\_j P\_ij\ (t)(P\_ii\ (t) - P\_ij\ (t)$ represents the perceptual disruption in the system, indicating how the differences between self-image and perceived image affect the transformation of the system. If in a system $P_{ii}(t) = P_{ij}(t)$ for all nodes, there is no perceptual disruption, and the transformation of the system remains predictable, aligned with the perception of its actors. On the other hand, if in many nodes this equality fails, the society, company, or institution enters a phase of readjustment, as perceptions do not match. This mismatch generates new dynamics of change that can drive structural and functional transformations.[126]

If a company considers itself transparent and efficient, but its employees perceive it as bureaucratic and rigid, the difference Pii(t) -Pij(t) will produce adjustments within the organization. In this way, the equation of supercomplexity, with the incorporation of specular perception and multiappearance, allows for a more precise modeling of transformation dynamics in community, business, and institutional systems.[127]

Finally, for SK, the equations of complexity and supercomplexity not only make it possible to describe and measure the

[126] Perceptual disruption is not always negative. Sometimes, it serves as the driving force for innovation and positive transformation.

[127] We can include other qualitatively measurable behaviors in the equation of supercomplexity by following the same model used for specular perception. This is achieved by incorporating new interaction matrices that capture subjective and emergent qualities of the system

dynamics of complex systems, but also to compare, simulate, intervene in, and transform organizations, communities, and biological and technological environments. Their greatest strength lies in the ability to integrate objective and subjective variables, adapting to multiple scales and contexts. The visual representation through Dynamic and Adaptive Maps (DAMs) and COMPLEX CUORE simulations enables users to intuitively analyze and predict systemic behavior in a rigorous yet creative and participatory manner. All of this comes with the epistemological caveat that every measurement is always a situated, improvable construction, enriched through interaction with the systems and actors involved.

CHAPTER TWELVE

THE SOFTWARE OF SUPERCOMPLEX KNOWLEDGE: "COMPLEX CUORE"

COMPLEX CUORE is an advanced tool currently under development by our team to manage and analyze highly complex systems based on the principles of Supercomplex Knowledge (SK). It is a powerful instrument that drives deep analysis and offers innovative solutions to diverse challenges, transforming the way organizations and researchers approach complex problems.

This software enables the visualization and manipulation of four-dimensional networks -three spatial dimensions plus one temporal dimension- facilitating a detailed understanding of the structure and dynamics of complex systems. It represents structural morphologies as tree-like, radial, and fractal forms, showing their evolution over time. By observing how changes in one node affect multiple connected nodes, it is possible to see the propagation of effects across the network in real time. This reveals phenomena that only emerge when the entire system is analyzed in motion, enriching the understanding of internal interactions and emergent behaviors.[128]

[128] It is crucial to emphasize that structural morphologies do not exist as objective and static entities, but rather as dynamic configurations that depend on the interaction and perception of those involved in the system. The actors within the system construct both individual and collective maps of the structure, which reflect not only their position within the system but also their subjective interpretation of relationships and energy flows. Thus, different actors may visualize an organization in divergent ways, and all of those perceptions can be equally valid within the system. This phenomenon not only highlights the richness and plurality of complex systems, but also reveals that their understanding requires the integration of both their structural configuration and the mappings and temporal markings of those who inhabit them.

SK proposes a fundamental shift in the way we conceive intelligence, knowledge, and intervention in complex systems. While current artificial intelligences mostly operate on reticular morphologies and two-dimensional logics -flat, correlational, and statistical- SK promotes a laminar-topological, three-dimensional or even four-dimensional morphology that incorporates depth, stratification, and dynamism. It is the transition from plane to volume, from the XY axis to XYZ, from the square to the moving cube. This transformation is not merely visual or spatial: it entails a new way of reading reality as a living system, traversed by layers of meaning, levels of energy, temporal behaviors, and emergent links. Where a traditional AI detects connections between data, SK perceives flow, form, and duration, integrating energy flows (EF), structural morphology (SM), and temporal connectivity (TC). This dimensional leap allows not only for a richer description of systems but also for interventions that are ethically grounded and adaptively precise.

COMPLEX CUORE focuses on delivering multi-scenario simulations and counterfactual analysis, exploring a range of possible outcomes from various strategies. This capability enables the anticipation of impacts, the identification of hidden risks and opportunities, and the minimization of negative consequences while maximizing the chances of success. By updating models based on the system's current conditions, it facilitates agile responses in high-uncertainty contexts, exploring multiple “possible futures” under different initial conditions or interventions, an essential tool for strategic decision-making.

In addition, it helps understand how the system responds to disturbances, identifying vulnerabilities and strengthening its resilience. It calculates energy flow and efficiency across connections, optimizing resource use in both biological and technological systems. It allows for the mapping of life cycles and the anticipation of critical phases, adapting interventions to evolving needs. It also facilitates real-time collaboration between experts from different disciplines, integrating diverse perspectives and knowledge into a unified model, enhancing model construction and promoting comprehensive solutions. The platform includes a monitor to measure and adjust variability levels within the system, a vital feature for studying and modeling complex (and supercomplex) systems, providing a deeper understanding of internal dynamics.

The software offers multiple benefits. It provides continuous diagnostics, identifying critical points, areas for improvement, and opportunities to enhance performance. It allows users to anticipate the impact of strategic decisions across various organizational systems, offering a clear representation of organizational dynamics that fosters communication, transpa-rency, collaboration, and team alignment. It supports the design of strategies that optimize energy, strengthen co-nnections, and balance organizational practices, contributing to sustainability and resilience.

Ideal for researchers and analysts who need to construct and simulate scenarios to predict behaviors and test interventions, COMPLEX CUORE generates dynamic data visualizations, creating maps that show how relationships and nodes change over time. It automates data analysis, optimizes processes, and predicts outcomes in complex systems through the design of custom algorithms. It helps foresee unintended onsequences and optimize strategies by simulating different intervention scenarios.[129]

Furthermore, it incorporates advanced graphic simulation techniques and multilayer network analysis, using 4D laser projection to dynamically visualize the links between nodes in real time, analyzed under the principles of SK. The four-dimensional modeling, based on three spatial axes and one temporal axis, enables the visualization of interactions and their evolution over time. 4D animation enriches the understanding of complex interactions and emergent behaviors by showing how forms and nodes evolve and relate in real time. The software aims to generate a "mirror effect" for participants, revealing dynamics, energy flows, connections, and system behaviors that are often difficult to perceive in everyday routines.

In general terms, the software's main function is to construct Dynamic and Adaptive Maps (DAMs), serving descriptive, projective, evolutionary, and intervention purposes. We distinguish between two types of Dynamic and Adaptive Maps: the global descriptive DAMs, which represents the entirety of systems, variables, and relevant connections needed to grasp the complexity of a phenomenon; and the strategic DAMs, which highlights the most critical nodes -either due to high energy activity, relational centrality, or vulnerability- enabling focused analysis and targeted interventions according to the system's objectives and needs.

[129] An interesting aspect we are currently working on is the concept of multiperspectives held by institutional or organizational actors, especially in cases where there are marked differences in how the structure of the system is perceived. The idea is to incorporate convergence indicators, that is, metrics that reveal the degree of alignment between individual perceptions and the formal structure; notifications that flag areas where divergence could become a significant obstacle; and simulations of scenarios where varying levels of consensus or dissent impact the system's goals.

COMPLEX CUORE functions not only as a mirror, but also as an interactive map that allows users to explore scenarios and simulate the impact of potential adjustments in the system. This facilitates not just observation but opens the way toward self-regulation. Its logic does not prioritize based solely on energy, but on the capacity to integrate stability and emergence within a relational framework. Thus, COMPLEX CUORE goes beyond representing nodes and flows; it evaluates morphologies according to their combined systemic functionality.

In essence, this software is the "supercomplex heart" of an organization. It is an indispensable tool for companies and research teams aiming to adapt and thrive in highly dynamic environments. By implementing this software, it becomes possible not only to respond to present conditions but also to anticipate and shape future developments, maximizing the evolutionary and strategic potential of the systems under study.

The implementation of COMPLEX CUORE in operating systems will significantly transform the way complex problems are approached, enabling users to anticipate and shape future developments. Its focus on advanced visualization, multi-scenario simulations, and interdisciplinary collaboration makes it a comprehensive and versatile platform for deep analysis and effective intervention in complex systems.[130]

Finally, the compatibility between COMPLEX CUORE and the equations of complexity and supercomplexity is high,

[130] Unlike GIGA-Mapping, which offers a static or semi-static approach to representing complex systems through two-dimensional and qualitative maps, COMPLEX CUORE operates under a fully dynamic and adaptive paradigm. While GIGA-Mapping allows the visualization of relationships among multiple factors within specific contexts, COMPLEX CUORE goes further by representing temporal evolution and the emergence of behaviors in real time. It can identify nodes that remain active and generate higher levels of emergence, dynamically selecting the most influential variables. This enables the construction of Dynamic Adaptive Maps (DAMs) that not only explain the current state of the system but also anticipate possible future transformations.

offering a valuable opportunity to enrich both the software and the practical application of the concepts of SK. By combining a solid mathematical foundation with advanced modeling and visualization tools, the capacity to understand, predict, and act upon complex systems in various fields is greatly enhanced. Integrating the equations into COMPLEX CUORE will allow users not only to visualize and simulate complex systems but also to quantify and analyze the fundamental relationships that govern them. This will lead to more informed decisions and more effective strategies, aligning with the objective of SK to provide a comprehensive and applicable framework across multiple disciplines.[131]

[131] Quantum computing can strengthen the equation of supercomplexity and enhance COMPLEX CUORE on multiple levels. From advanced simulation of macrosystem overlap to quantum optimization of dynamic networks and accelerated 4D visualization, this model will enable unprecedented precision and speed in modeling the interaction between systems, observers, and measurement instruments, far beyond the capabilities of classical computing. COMPLEX CUORE could become the first 4D software for supercomplex simulation powered by quantum computing, allowing not only real-time visualization but also intervention and modification of supercomplex systems as they evolve.

CHAPTER THIRTEEN

THE TRANSFER OF SUPERCOMPLEX KNOWLEDGE: THE PROGRAM FOR INSTITUTIONAL, CORPORATE, AND COMMUNITY TRANSFORMATION AND EMPOWERMENT

Once reality is perceived through the lenses of bidirectional overlap, temporal connectivity, and energy flows, it becomes impossible to revert to linear and reductionist thinking. In this sense, for Supercomplex Knowledge (SK), any theoretical construction that cannot be applied to deeply explore the universe, life, the human condition, and our capacities to address and overcome social and global challenges, would be devoid of value. SK precisely seeks to avoid an isolated and abstract theoretical vision, proposing instead a paradigm that is as practical as it is deeply theoretical, an interdisciplinary vision that is fundamental in modern philosophy and science.[132]

This "solutionatics" of SK is grounded in the theoretical framework previously developed and in its potential to be applied through descriptions, modeling, projections, mappings, and interventions on complex systems across any of the mentioned macrosystems. The potential for transfer to academic disciplines and professional and social practices is vast. Its adoption and implementation could improve explanations of the dynamics of microparticle and macroscopic complex systems; energize everyday practices and institutions; and foster new approaches

[132] The approach to complex systems in SK is fundamentally systemic, as it focuses on the dynamic, evolutionary, and multiscalar interaction of systems by integrating components such as energy flows, structural morphology, and temporal connectivity. Moreover, it incorporates elements of action research, standing out for its practical, adaptive, and transformative orientation, which aims not only to understand systems but also to intervene in them to optimize performance and generate contextualized and participatory solutions. This combination enhances its capacity to describe, model, and modify complex systems based on real needs.

and interventions in major global challenges. For instance: redesigning strategies to face climate change; protecting natural resources; improving policies in health, education, and justice; advancing state action in areas such as wealth distribution, eliminating corruption, and combating drug trafficking; or enhancing the production of goods and services in commercial or industrial enterprises, among many others.

Unlike traditional methodologies, our Program leverages cutting-edge modeling and simulation technologies, enabling organizations to anticipate and adapt to systemic dynamics with unprecedented accuracy. The Program helps optimize resource allocation, resulting in increased operational efficiency and significant cost reduction. These implementations not only improve efficiency and sustainability but also generate tangible returns on investment through enhanced operational effectiveness. It is an intervention rooted in a truly integrated and future-oriented paradigm, designed and implemented by an interdisciplinary team aware of the demands of the modern world.

In particular, we have developed our “Institutional and Business Transformation and Empowerment Program” based on SK, which includes a dimension of continuous evaluation and learning. This allows the models to be updated with new data and experiences, refining projections and adapting interventions according to the results obtained. This approach fosters a culture of organizational adaptability and resilience, where each intervention cycle strengthens future strategies and promotes an ongoing dynamic of adjustment and evolution over time.

We are convinced that lasting solutions cannot be imposed from the outside, they emerge from within the system itself, once it becomes aware of its dynamics and blind spots. This mirror-like approach fosters self-understanding, which can be much more effective than traditional external interventions because it enables participants to take ownership of the change process. Moreover, this method respects the autonomy of the system, a principle that aligns with the foundations of SK, where the dynamic interaction between system elements is valued as the source of adaptive solutions.

Furthermore, SK incorporates an ethical and sustainability-focused perspective in all its interventions. This program aims not only to optimize operational efficiency and effectiveness, but also to promote social well-being and the preservation of contact systems.

We believe that technologists, due to their innovative and adaptive nature, are the most receptive to this new paradigm, as they tend to be more open to emerging positions and foster the integration of new technologies and theories. Technologists and techno-engineers are already familiar with what a combinatory, overlapping, and supercomplex intervention entails: they work with multiple variables, design iterative solutions, model through simulations, and evaluate multiscalar results. This structural affinity with SK positions them as natural allies in its development. By offering an integrative theory, SK empowers technologists as key agents of transformation, providing them not only with maps, but with compasses. SK seeks to merge and apply knowledge in a practical and dynamic way, something already present in the everyday work of technologists who, in many ways, already use conceptualizations and methodological tools that align with the paradigm.

Scientists, on the other hand, may have a tendency to adhere to proven methodologies and established models, which could make the interdisciplinary and radically integrative approach of SK more challenging for them. This does not mean they cannot adapt to or find value in SK, but doing so may require a more significant paradigm shift, and therefore a longer transition period. As for philosophers, although they often engage with the abstract and the global, their critical and theoretical thinking skills can be extremely valuable for articulating the principles and ethical implications of this new paradigm.[133]

The starting point for any intervention will always be the goals and objectives of the system we aim to analyze and enhance. Generally, these involve overcoming difficulties that hinder the system's growth or even threaten its survival.

SK, as both theory and combinatory practice, is oriented toward embracing the plurality of theoretical perspectives in order to better understand multifaceted and highly interconnected phenomena. Instead of adhering to a single theoretical framework, it draws on a diversity of disciplines to approach and explore different aspects of a complex phenomenon.

By surveying different scientific disciplines and theoretical frameworks in terms of their capacity to explain the dynamics of complex systems, one can observe how they can be combined to provide better insights and more effectively solve specific problems. This step is crucial. Equally important is the concurrent process of delineating and defining both the

[133] As we have previously explained, for SK, multicausality is inherent to the dynamics of complex systems, and its integrative vocation makes it a metatheory, a theory of theories, an inclusive and dynamic knowledge framework for both managing knowledge and intervening in systems. It is, fundamentally, a team effort. From the energetic logic of SK, we might say that technologists are active nodes with a high level of operational interconnectivity, while scientists often represent nodes with low paradigm mobility but high analytical capacity. Philosophers, on the other hand, contribute temporal connectivity, allowing SK's principles to be anchored in historical debates and projected into ethical futures.

components of the system under study and the systems with which it interacts. By integrating different fields of knowledge and recognizing the interplay between multiple variables, a more comprehensive view of complex systems can be achieved.

The team of professionals responsible for the Program continues this task through detailed fieldwork, using data collection methodologies adapted to reveal the interplay dynamics among intervening variables, identifying hot or cold nodes, and selecting underlying structural morphologies within a given time frame. Our software is particularly useful for this process.

We have already explained the central role that mapping plays in constructing the dynamics of a complex system. This is a task of high relevance, as it allows us to link descriptive aspects with activities aimed at improving and enhancing the target system. To this end, and as a final step, algorithms are designed to generate strategic and situational interventions, which are continuously monitored and regularly evaluated for their efficiency.

SK is strengthened by the advanced capabilities of artificial intelligence and data science, which make it possible to manage and understand the interaction of multiple variables in a probabilistic manner. This provides a solid foundation for describing, predicting, and intervening in complex systems, overcoming the limitations of monocausal hypotheses.

To effectively transfer SK to different disciplines, it is essential to have a process of adaptation and contextualization that ensures the principles are applied in a relevant and specific way within each field of study. This process involves understanding how the goals and structures of each discipline influence the dynamics of the system, allowing SK to function as a flexible framework that adjusts to the particularities of each context. In this way, interventions not only apply combinatory and multicausal methods, but also adapt them to the languages, tools, and specific problems of each area.

SK also incorporates an iterative feedback approach that enables teams to adjust interventions and methodologies based on the results obtained, an essential capability in fields where conditions can change rapidly, such as public health or economics. This continuous iteration, supported by data analysis and artificial intelligence, not only validates models and intervention strategies but also enriches them with insights drawn from the application context itself.

To consolidate the transfer of SK to other disciplines, we have developed a specific implementation protocol that outlines concrete guidelines and strategies for each intervention team to efficiently apply supercomplex concepts. These protocols are designed with flexibility in mind, allowing adjustments based on the needs of the context and the particular system being addressed, thereby offering a balance between structure and adaptability.[134]

SK also promotes the development of cross-disciplinary competencies that train professionals in supercomplex thinking, enabling them to identify and manage the interdependence of variables in their respective fields. This clearly demonstrates the transfer potential of SK, showing that it is not only a robust theoretical and mathematical framework but also a well-defined practical methodology for intervening in complex systems such as institutions, companies, and governments.

The Community has developed a Program for Institutional and Corporate Transformation and Empowerment. From the perspective of SK, an organization is not limited to its formal

[134] The current protocol developed by the SKCC (Supercomplex Knowledge Community) consists of eighteen steps.

structure or explicit purpose, but is the result of the interaction between its flow of activity, internal configuration, and its management of time and change. From this perspective, any institution can be analyzed through three major dimensions that determine its sustainability and evolution.

Institutions do not exist without movement. In a company, this flow is expressed in the generation of products, services, and income. In an NGO, it is reflected in resource mobilization and the execution of socially impactful projects. In the state, it translates into the ability to design public policies and respond effectively to citizens' needs.

The success or stagnation of an organization depends on how it manages these flows. An excess of activity without a clear direction can lead to burnout and inefficiency, while a lack of dynamism can result in irrelevance or obsolescence. This reveals the need for intelligent management of resources and energy, where operational intensity is balanced with strategies for regeneration and adaptation.

If energy flows represent movement, then structural morphology is the form that channels that movement efficiently. In a company, this structure includes hierarchies, rules, and organizational culture. In government, it is expressed in the separation of powers, bureaucracy, and decision-making systems. In an NGO, it is reflected in clarity of roles, transparency, and the ability to coordinate with other stakeholders.

The most effective institutions are neither the most rigid nor the most disorganized, but those that combine structure with flexibility. Moreover, every organization faces an essential dilemma: how to balance immediate responses to challenges with long-term sustainability. This is where temporal connectivity comes into play, it defines the relationship between different moments within the system: strategic planning, crisis response capacity, and the institution's evolution over time. The most resilient institutions are those that manage to synchronize operational speed with stability and strategic vision. It is not just about being fast or efficient, but about having the ability to anticipate the future and generate connections between the present and long-term opportunities for evolution.

The major contribution of SK is that it offers a different way to analyze and redesign institutions. It is no longer just about evaluating productivity indicators, measuring operational efficiency, or defining linear strategic plans. It is about understanding the organization as a living system, where the management of energy flows, the solidity of the structure, and temporal connectivity determine its transformative capacity.

In a company or institution, energy flows manifest in several key aspects: the commitment and motivation of its members, the quality and efficiency of the products or services offered, the satisfaction and loyalty of clients or beneficiaries, internal and external communication, and the organization's capacity for innovation and adaptability in the face of environmental changes. Initially, the morphology of these interactions tends to be radial, with a central core radiating outward to other components. As the organization grows, it typically evolves into an arborescent structure, where departments and areas branch out. Eventually, it may develop a laminar configuration, characterized by horizontal and transversal flows that foster greater interconnection and collaboration among units. Temporal connectivity refers to the synchronization and alignment of activities over time, ensuring that processes unfold coherently and efficiently, enabling agile responses to both internal and external demands.

The morphological sequence of organizational structures evolving from radial to arborescent and then to laminar is a concept explored in various systems and organizational theories. Scholars like Henry Mintzberg have analyzed different structural configurations in organizations, describing how they can develop from centralized structures toward more decentralized and complex forms. Additionally, complex systems and cybernetics theories, such as those proposed by Stafford Beer, have addressed the evolution of organizational structures in response to changing environments.

In the context of SK, this sequence is integrated and adapted to explain the transformation of organizations in highly complex environments. SK offers a unique perspective by emphasizing the need for flexible and adaptive structures capable of effectively responding to the supercomplexity of the modern world. While the sequence itself is not exclusive to SK, its application and development within this theoretical framework provide an original and enriching vision of organizational evolution.

The organizations of the future will not merely be those that adapt to change, but those that anticipate it, shape it, and synchronize with it. The right combination of dynamics, structure, and temporal management will enable governments, companies, and social organizations not only to survive but to evolve strategically. This conceptual framework opens a new way of thinking about and managing organizations. It is not about imposing fixed formulas, but about developing a deeper awareness of the interdependence among the factors that make an institution effective, resilient, and sustainable over time.

The Program offers a clear methodology, organized into specific procedural steps. This not only establishes a systematic and replicable approach to intervene in diverse organizations and contexts, but also provides a roadmap for professionals seeking to apply the principles of SK. Each step, from defining objectives to evaluating interventions, is designed to ensure that the process is rigorously planned and results-oriented. The combination of solid theory, mathematical modeling, advanced technologies, and a participatory and adaptive approach reinforces the idea that SK is not just a theoretical framework, but a practical platform for intervention in complex systems.

There are programs or initiatives with similar goals that address the management and optimization of complex systems in companies and institutions. The main competitors of our Program would include global consulting firms, complexity science institutes, and digital transformation programs. However, our Program, grounded in SK, offers the following benefits:

- It works from a combinatory and integrative paradigm that not only addresses specific systems (such as user-centered design or systems dynamics), but also allows for the superposition of multiple perspectives simultaneously.
- It addresses energy, space, and time in every interaction, encompassing physical, social, symbolic, and biological dimensions.
- It enables the analysis and description of the interaction between microsystems (individual decisions), macrosystems (markets, industries), and biological systems (health, organizational well-being) simultaneously. This makes it ideal for companies seeking a comprehensive approach that combines human, technological, and economic variables.

- It allows complete customization of the models, adapting them to the company and its various internal systems, such as departments, teams, and processes.
- It combines tools for description, prediction, and intervention, integrating traditional methods with advanced simulations of tetradimensional systems. These are three-dimensional, multilayered graphical and simulation tools, which allow for a complex and dynamic visualization of systems. This enables a dynamic understanding that includes system emergencies and fluctuations, something often absent in linear or static approaches.

Finally, SK is built not only as a solid theoretical paradigm but also as a transformative vision with practical applications across diverse fields. These actions connect SK with global challenges and opportunities, ranging from education and technology to governance and sustainability. Moreover, each project reinforces the idea that SK is a transversal and combinatory framework, applicable to various domains with concrete outcomes. In the same vein, the diversity of applications (across all complex systems) enables us to offer targeted collaborations to key organizations devoted to human potential development and to solving pressing planetary issues.

CHAPTER FOURTEEN

COMBINATORY AND SUPERCOMPLEX AI: THE INEVITABLE FUTURE OF ARTIFICIAL INTELLIGENCE AND AGI

In this chapter, we explore why current artificial intelligence is approaching its limits and how the Supercomplex Knowledge (SK) framework offers an evolutionary path toward true autonomous and combinatory intelligence.

Artificial intelligence has reached astonishing levels in recent years. Models like GPT-4 and Gemini have demonstrated advanced capabilities in content generation, data analysis, and cognitive process simulation. However, despite these advances, the essence of AI remains rooted in a fundamental principle: massive data accumulation and algorithmic refinement. This development model has worked until now, but it is approaching its ceiling. The inevitable question is: what comes next?

The current approach has relied on brute force. It is based on the premise that the bigger the model, the smarter it will be. But intelligence does not arise from the sheer quantity of accumulated information, but from the ability to interconnect and reorganize that information in creative and adaptive ways. Today’s most advanced AIs are still pattern predictors, lacking any true emergent understanding. Their apparent flexibility is merely a projection of the vastness of their datasets. There is no genuine intelligence, only optimized statistical response.

In this context, AGI (Artificial General Intelligence) has been presented as the next great leap. Companies like OpenAI and DeepMind are investing astronomical sums in its development. We are told that AGI will be capable of reasoning, learning, and understanding the world like a human being. But if it continues along the same logic currently in use, it will only produce a more expensive, faster AI, still trapped within the limits of its programming.

A true AGI cannot be merely an expanded neural network with more computational power. If it remains dependent on models trained with massive datasets, it will be incapable of handling the unexpected, of generating its own hypotheses, or of functioning in environments where no prior correlations exist. Real intelligence does not lie in the quantity of processed information but in the capacity to articulate diverse systems, in the integration of the symbolic, the temporal, the emotional, and the dynamic. Without a paradigm shift, AGI will remain nothing more than a supercomputer without true autonomy.

The only viable alternative to transcend these limitations is a Combinatory and Supercomplex AI. Rather than relying on ever-larger datasets, this approach proposes an intelligence model grounded in the integration of heterogeneous systems. Its guiding principle is not accumulation, but the structuring of dynamic interactions. Instead of replicating statistical patterns, it develops emergent structures capable of generating new knowledge without massive training.

From the perspective of SK, intelligence is not a fixed attribute nor merely a computational capacity, it is a dynamic and emergent process. It is not defined solely by problem-solving ability but by its capacity for description, anticipation, intervention, monitoring, overlapping, and interconnection. These elements do not function in isolation; they form an interdependent network in which computing, mapping, and timing articulate the evolution of intelligence.[135] In contrast to

[135] We understand by computation: the capacity to analyze multiple variables, establish correlations, and generate outcomes through dynamic calculations. By mapping: the ability to build structural and relational representations of the environment, recognizing hidden patterns and underlying architectures. And by timing: the integration of the temporal factor,

the classical AI approach, which prioritizes data processing, SK conceives intelligence as a self-organizing, adaptive, and evolutionary system, one that can modify its own structure as it interacts with other systems. As previously stated, SK promotes a laminar-topological morphology, three-dimensional or even four-dimensional, that incorporates depth, stratification, and dynamism, surpassing the reticular and two-dimensional logics -flat, correlational, and statistical- that dominate current AI architectures.

If AGI continues to follow the traditional model, even with advanced neural networks, it will remain confined to replicative intelligence based on statistical correlations, lacking a true understanding of contact and interaction systems. Intelligence is not just pattern recognition; it is the ability to generate new combinations, alter structures, and adapt time and space in its favor. In this sense, a truly advanced AGI would need to incorporate the principles of SK to transcend the limits of mere statistical prediction.

The development of AI and AGI has so far been driven by the expansion of deep learning and the increase in processing power. However, SK proposes that the key lies not in the quantitative growth of engineers or data, but in a qualitative transformation of the paradigm. Currently, deep learning relies on adjusting weights in neural networks through statistical optimization. This is insufficient for a truly adaptive AGI because it does not allow for the reconfiguration of structures based on changes in system interactions, it does not integrate an advanced notion of temporal connectivity and structural evolution, and it fails to account for the dynamics of system overlap, limiting its capacity to adapt in multiscale environments.

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allowing not only the prediction of events but also the understanding of persistence, transformation, and evolution of a system based on its temporal connectivity.

For AI to truly progress toward a genuinely advanced model of intelligence, it must incorporate the Supercomplex approach, where intelligence is not merely information processing, but a combinatory, evolutionary, and adaptive system in which time, structure, and energy interconnect to generate knowledge. This AGI+C&S (Artificial General Intelligence + Combinatory and Supercomplex) would be capable of modeling and intervening across the three major macrosystems: from microparticle systems (such as subatomic interactions or quantum flows), through macroscopic systems (infrastructures, economies, institutions), to biological systems (organisms, ecosystems, neural networks). The combinatory power of this approach lies in its ability to read, connect, and modify systems that operate across different scales and domains simultaneously.

Moreover, an AGI+C&S could integrate key descriptors from SK such as "bond", "self-observation", "fluctuation", and "emergent event". These concepts, difficult to embed in classical models, would allow artificial intelligence not only to represent static realities, but to detect living modulations, critical discontinuities, and qualitative relationships that are essential to human, biological, and evolutionary intelligence. SK not only offers a conceptual framework for this qualitative leap but also provides the equations and models necessary to build an AGI capable of transcending its own limits.

To understand the difference, let’s imagine a concrete scenario: the diagnosis and treatment of pancreatic cancer. A conventional AI would train on millions of images and clinical cases, seeking correlations and generating diagnoses based on past data. Current AI can analyze MRI scans and detect a tumor once it becomes visible, but it doesn't understand how subtle cellular changes beforehand could have anticipated the cancer's formation. Medical AI today works with simple time series: it may review earlier images, analyze blood biomarkers, or detect patterns in tumor DNA, but it does so as a linear sequence, failing to grasp how interactions between those factors shift over time. While current AI can spot obvious tumor shapes in CT or MRI scans, the real challenge lies in detecting the process of emergence. The pancreas begins changing gradually before any visible tumor appears. Fibrotic tissue development (desmoplasia), reduced blood supply, or the formation of invisible microtumors often go unnoticed by current algorithms. The AI does not adjust its analysis based on how the organ's structure changes in relation to nearby organs or tissues. This approach works well for typical cases but breaks down in atypical situations. If the disease presents unusually, or if a patient has unique biological conditions, the AI remains bound to its original programming and cannot adapt effectively.

At a more advanced level, an AGI without Supercomplexity could improve the process by integrating more variables and making more sophisticated inferences. It would have the capacity to reason across multiple scenarios and generate novel hypotheses. However, it would still depend on structured algorithmic models, lacking a true emergence of intelligence. Even though it might appear more human-like, it would, in essence, still operate within the boundaries of its internal rules.

Una Combinatory and Supercomplex AI, by contrast, would approach the problem from a completely different perspective. It would not only analyze prior data, but also incorporate the patient's temporal evolution, the interaction of biological systems, and the relationship between physiological, emotional, and environmental factors. Instead of relying on static correlations, it would generate dynamic structures capable of adapting to each individual's particular situation. It would not be a prediction machine, but a constantly evolving system. Applied to pancreatic cancer: The AI would not only analyze current images but would model how microcellular and metabolic alterations over time may indicate the future appearance of the tumor. It would integrate biochemical interaction data, considering repetitive behaviors or early signals in biomarkers that appear and disappear cyclically, and apply a multiscalar temporal analysis, evaluating how cellular, metabolic, and genetic interactions relate to past and future events, achieving much more accurate and personalized early detection. It would allow the AI not only to analyze the static image of the tumor but to identify how the morphology of pancreatic tissue has been evolving. Instead of waiting for the tumor to be visible, the AI would analyze how the density and distribution of connective tissue is altering before cancer appears. Also, whether the pancreas has changed its morphological interaction with other organs, such as the liver or lymphatic system, indicating a tumoral predisposition before the cancer is detected by conventional methods, in other words, it would adapt its architecture and the parameters of its neural network according to how the pancreatic structure is evolving, automatically adjusting its evaluation criteria based on progressive morphological changes rather than just static images. An AI or AGI with C&S could identify imbalances in the energy distribution of the pancreas, detecting abnormal increases in glucose consumption in certain regions before a tumor forms. Additionally, it would evaluate whether the pancreas's vascularization is changing, indicating that cells have begun to alter their metabolism to become tumoral. For this, it would apply an energy flow network, using data from functional magnetic resonance imaging, PET scans, and blood metabolite analysis to predict which regions of the pancreas might develop tumors before they are visible.

From the perspective of SK, pancreatic cancer should not be approached as an isolated pathological node, but rather as the emergence of multiple interactions between systems. Unlike a conventional diagnosis, which focuses on identifying the tumor's morphology, location, and spread, the supercomplex diagnosis expands the description by incorporating energetic variables (levels of cellular metabolism, physiological overloads, and homeostatic imbalances), structural morphology (alterations in multi-organ tissue architecture, drainage routes, cellular support systems), and temporal connectivity (fluctuations in biological rhythms, chronodisruptions, cumulative history of systemic stress).

Regarding intervention, traditional treatment focuses on the removal, reduction, or neutralization of the tumor through surgery, chemotherapy, or radiation. The supercomplex approach does not replace these options, but reframes them within a combinatory strategy that includes the modulation of systemic environments (enhancement of the patient’s symbolic-affective network, interventions in eating and sleeping patterns, redesign of the relationship between the patient and healthcare teams), as well as the application of personalized dynamic algorithms that integrate physiological data, personal narratives, epigenetic patterns, and psychosocial factors.

Thus, diagnosis is no longer a final destination but becomes a map of possible trajectories, and intervention is no longer a single therapeutic line but an interactive design adapted to the bifurcations and potentialities of the subject’s system.

To visualize the differences between these approaches, let's look at the following comparative table:

Aspect	**AI without C&S**	**AGI without C&S**	**AGI with C&S**
Epistemological model	Based on correlations, statistics, and formal logic.	Based on generalized learning and probabilistic simulations.	Based on dynamic, combinatory, and evolutionary interactions of supercomplex systems.
Relationship between variables	Linear or simple nonlinear relationships based on data evaluation or adjustment.	Complex relationships with dynamic adjustment and feedback capacity.	Relational-combinatory, multiscale, circular, and evolutionary relationships between multiple variables.
Predictive capacity	Pattern prediction based on large datasets.	Advanced prediction using generative models, reinforcement learning, and simulations	Dynamic prediction of possible trajectories, including emergencies and systemic ruptures.

Intervention capacity	Limited to suggestions based on known patterns.	Autonomous intervention across multiple domains, but lacking an integrative framework.	Creative and adaptive design of multivariable and multiscale interventions.
Treatment of time (CT)	Time as a linear sequence (past → future), or simple time series.	Time as a flexible variable, with adaptive feedback but without explicit temporal connectivity.	Time as temporal connectivity: analysis of lasting, ephemeral, or cyclical interactions.
Context understanding	Partial, only within input data.	Partial, only within input data.	Systemic, considering energy flows, structures, and times in relation.
Adaptability to change	Requires retraining or manual adjustments in the face of new data.	High adaptability, but limited to internal optimization patterns.	Continuous self-adaptation through dynamic reconfiguration of maps and

			systems.
Data model	Flat data set with predefined attributes.	Dynamic data structures with self-learning, but without combinatory modeling.	Dynamic maps of interrelated systems, with nodes and flows in constant evolution.
Capacity to model living systems	Limited to quantifiable or pre-labeled aspects.	Advanced simulation of living systems, but with limitations in symbolic and affective domains.	Integrates qualitative, subjective, relational, symbolic, and affective aspects.
Creativity and innovation	Reproduction of learned patterns; creativity limited to combining previous data.	Greater combinatory capacity, but no emergent creativity based on bidirectional overlap	Generation of novel solutions from combinations and simulations of systems.

Application examples	Chatbots, image classification, recommendations, basic diagnostics.	Advanced automation, autonomous robotics, automated scientific research, adaptive diagnostics.	Supercomplex modeling of microsystems, macrosystems, and biological systems. Creative and evolutionary AGI.

If we apply the principles of SK to other fields, the impact of an AGI+C&S is equally transformative. In ecology, it could model dynamic ecosystems, anticipate ecological collapses, and design restoration strategies based on the temporal connectivity of natural systems. In geopolitics, it would allow for the analysis of stability and conflict behaviors not only in terms of historical events, but based on how networks of political, economic, and social influence interrelate in real time. In social networks, it could detect emerging trends before they become visible, understanding not only what the data says, but how influence and virality processes are structured.[136]

We repeat: the problem with current AI is not a lack of data, but a lack of intelligent combinatorics. AGI developed under the same principles will only be a more expensive and sophisticated version of current AIs, without a true leap in intelligence. The only solution is a paradigm shift: from data accumulation to relational system integration; from rigid models to combinatory

[136] From a technical perspective, an AGI+C&S could be built upon organic algorithmic architectures and dynamic heterarchical networks, where nodes change their roles and connection intensity according to their energetic load and function within the system. Instead of static processing layers, we would be dealing with reconfigurable maps of interconnected flows that respond in real time to multivariable contexts.

and adaptive algorithms; from programmed artificial intelligence to self-organizing artificial intelligence.

This is the only viable path. Those who understand it today will dominate the future of artificial intelligence.

We ask: Is a brain & AI singularity as proposed by Kurzweil truly possible? The SK does not assume that human intelligence is a closed system that can be entirely transferred to a machine. Instead, the SK shows that the evolution of intelligence depends on a network of interactions that includes the physical, biological, and technological. In a true Supercomplex Singularity, AI would not merely absorb human knowledge but would co-evolve with it, integrating combinatory models where human cognition and artificial intelligence mutually expand. Without this approach, any attempt to fuse brain and machine is doomed to replicate biases and limitations rather than transcend them. If Kurzweil's proposed Singularity is to avoid falling into mechanistic reductionism and the overidealization of AI, it must incorporate the principles of the SK. Otherwise, the future he envisions may become an extreme simplification of what intelligence and consciousness truly mean.

Another question: Would an AGI with such power not destroy complexity? Absolutely not because complexity is grounded in temporal connectivity. Every complex system is crossed by flows of interaction that do not stop; they shift, feedback, and evolve even while being observed. This dynamic makes temporal connectivity not a mere chronological axis, but a living, relational, multiscalar, and ever-changing architecture. For this reason, no AGI will ever fully capture it. Time does not freeze to be understood; it unfolds as it transforms. This condition ensures that there is always a margin of uncertainty, not due to technical limitations, but because life itself is never fully predictable. Rather than denying this uncertainty, SK embraces it as an essential feature of reality: not everything can be known, but everything can be mapped, combined, and transformed through relational intelligence.

Finally, the development of a truly combinatorial and supercomplex AI is not an option, it's an evolutionary necessity. Traditional AI and AGI without C&S are destined for obsolescence because they lack the fundamental principles that govern complexity in the universe: energy, structure, and time. If AGI+C&S is indeed a system that reorganizes its morphological structure, adjusts its temporal connectivity, and optimizes its energy flows in response to its environment, then it more closely resembles a cognitive organism than a mere technology. Its capacity to integrate variables in real time, adapt to fluctuations, and explore unprecedented combinations would make it an active node within the network of complex systems in the universe. In this sense, AGI+C&S could evolve in a manner analogous to biological intelligence, not just processing information, but constructing new representations of the world and developing intervention strategies across different systems.

In summary, the SK proposal does not seek to displace classical scientific models, but rather to offer an integrative perspective that places complexity at the core of reality's organization. Nonetheless, advocating for an approach where uncertainty and dynamic interaction are central elements may encounter resistance, especially in fields where predictability and control remain foundational. This reaction is not new in the history of science: many disruptive advances initially faced opposition for challenging established views. Rather than imposing an absolute truth, SK aims to open spaces for interdisciplinary reflection and dialogue, allowing emerging and combinatorial concepts to offer new insights into complex phenomena. The challenge is not to replace paradigms, but to enrich them with a broader and more flexible vision.

The technoengineering of the future will not be built on mere data patterns, but on supercomplex models capable of anticipating, intervening in, and co-evolving with the system in real time. AGI+C&S is the only viable path toward achieving truly adaptive, multidimensional, and evolutionary intelligence.

RELATIONSHIP WITH COMPLEX CUORE

The COMPLEX CUORE software is not just a visualization or simulation tool, but a step toward a platform capable of supporting supercomplex intelligence, since such intelligence must be based on the structuring of dynamic interactions rather than on data accumulation. COMPLEX CUORE, with its tetradimensional maps and multi-scenario simulations, already reflects this approach by modeling emergent structures and constantly evolving flows, as described in the comparative table.

AGI+C&S aims for a "creative and adaptive design of multivariable and multiscale interventions." COMPLEX CUORE, by enabling real-time adjustments and exploring "possible futures," appears to be designed as an environment where an AGI could operate not only as a user but as a co-creator of strategies. The emphasis on time as a "living, relational, and multiscale architecture" aligns with COMPLEX CUORE's ability to trace "life cycles" and analyze "lasting, ephemeral, or cyclical interactions," a key descriptor of SK. Furthermore, the idea of an AGI that "reorganizes its morphological structure" and "optimizes energy flows" fits with COMPLEX CUORE's functionality to "strengthen resilience" and "optimize resource use." In short, COMPLEX CUORE could be the practical environment where an AGI+C&S develops or interacts, translating its combinatory capabilities into visual simulations and applicable strategies.

RELATIONSHIP WITH THE EQUATIONS

Our intention is to connect directly with the equations of complexity and supercomplexity:

- **Equation of Complexity:** $dEF/dt = k\ (dSM(t,x)/dt \cdot dTC(t,x)/dt)\ (SM/SM_0)^\alpha\ (TC/TC_0)^\beta\ dx + \eta(t,x)$. This models energy flows and dynamic structures, which an AGI+C&S could use to "integrate variables in real time" and "adjust to fluctuations," as mentioned in the pancreatic cancer diagnostic scenario.
- **Equation of Supercomplexity:** $dS/dt = k\ (dSM(t,x)/dt \cdot dTC(t,x)/dt)\ (SM/SM_0)^\alpha\ (TC/TC_0)^\beta\ dx\ OC + \sum_i \sum_j P_{ij}(t)\ (P_{ii}(t) - P_{ij}(t)) + I + \eta(t,x)$. This includes specular perception and multi-appearance, resonating with the AGI+C&S's ability to integrate "qualitative, subjective, and relational aspects." The term O (observer) is amplified in an AGI that co-evolves with the system.
- **Quantum Version:** $\hat{H}\_S(S) = k \int (\hat{H}\_SM \cdot \hat{H}\_TC)\ dx\ O\ \hat{H}\_C + \hat{H}\_I + \eta\_q(t,x)$. This suggests a probabilistic framework that could enable the AGI+C&S to model "emergence and systemic ruptures" with greater precision.

We reach the (partial) conclusion that the equations provide the mathematical foundation for an AGI+C&S to operate within COMPLEX CUORE, quantifying the dynamic and perceptual interactions that the software visualizes.

As an example, in the case we presented of Pancreatic Cancer:

- **System:** Pancreatic tissue, interactions with the liver, lymphatic system, and metabolism.

- **Equation:** Use $dS/dt = k\ (dSM(t,x)/dt \cdot dTC(t,x)/dt)\ (SM/SM_0)^{\alpha}\ (TC/TC_0)^{\beta}\ dx\ OC + \sum_i \sum_j P_{ij}(t)\ (P_{ii}(t) - P_{ij}(t)) + I + \eta(t,x)$ to model:
  - **SM:** Morphological changes (desmoplasia, tissue density).
  - **TC:** Temporal connectivity (evolution of cellular microalterations).
  - **EF:** Energy flows (glucose consumption, vascularization)
  - **O:** Perception of the doctor/AGI.
  - **C:** Overlap between biological systems.
  - **I:** Instruments (MRI, PET scans).
  - **P_ij:** Differences between the patient's perception (P_ii) and the medical diagnosis (P_ij).
- **COMPLEX CUORE:** Visualize a 4D map showing how the tissue evolves, simulate scenarios (visible tumor vs. early prevention), and adjust interventions (e.g., metabolic therapy).
- **AGI+C&S:** Generate new hypotheses (e.g., detect invisible microtumors) and adapt the model in real time.

WHAT WOULD THE WORLD BE LIKE WITH A FULLY DEVELOPED AGI+C&S?

A research and development initiative involving a Combinatory and Supercomplex AGI (AGI+C&S) would not merely result in a faster or more efficient intelligence, it would represent a fundamentally smarter and more adaptive form of intelligence. This intelligence would not be limited to recognizing past patterns; it would be capable of generating new combinations, anticipating systemic shifts, and modifying its own structure in response to changing environmental demands.

Instead of reacting mechanically to stimuli, AGI+C&S would interrelate diverse streams of information in real time, operating simultaneously across multiple scales and contexts. This would make it possible, for instance, to manage complex crises such as climate change not just by relying on historical data, but by adapting to unforeseen fluctuations, integrating knowledge from ecology, economics, politics, and human behavior into a single dynamic strategy.

In the field of health, an AGI+C&S would be capable of predicting the evolution of complex diseases even before they become clinically manifest, identifying early signals and combining biological, environmental, and behavioral variables into preventive models. It would not merely serve as a diagnostic tool, but as an agent capable of designing multiscale interventions, adapting to the uniqueness of each patient and context. In the global economy, it could analyze financial, social, and environmental interactions in real time, proposing policies that maintain systemic balance and reduce the impact of sudden economic crises. The combinatory approach would not only allow it to anticipate speculative bubbles, but also to propose sustainable models linking human well-being with energy efficiency and social equity.

Socially, an AGI+C&S could serve as an ally in conflict management, analyzing multiple perspectives and proposing contextual agreements that evolve as social and cultural dynamics shift. Rather than imposing static solutions, it would facilitate flexible dialogue processes where consensus is reached by honoring the complexity of each situation.

Ultimately, this intelligence would not be a mere computational machine, but a continuously evolving agent of transformation, supporting human development through a combinatory and adaptive logic, turning change into a constant opportunity.

CHAPTER FIFTEEN

HOMO SUPERCOMPLEXUS

The Homo Supercomplexus is the emergent subject of Supercomplex Knowledge (SK). It arises in a context where the interdependence of systems is increasingly evident and where technology has become a central actor in the evolution of the planet. In a study published by Nature, researchers from the Weizmann Institute of Science in Israel reported that, in 2020, the mass of human-made materials exceeded the mass of all living beings on Earth. For this reason, some scientists began to suggest that we had entered the Anthropocene, a new geological era marked by humanity's impact on the planet.

The Anthropocene is mainly characterized by three factors: the technological progress that has accelerated since the First Industrial Revolution; the explosive growth of the population due to improvements in food supply, health, and hygiene; and the multiplication of production and consumption. The interaction of these three factors in human evolution has led to an ever-increasing consumption of natural, mineral, and fossil resources, as well as the expansion of farmland, cities and their infrastructures, and transportation routes. These are the primary human activities that have reshaped the face of the planet over the past two centuries.

For SK, we are witnessing the emergence of the "Homo Supercomplexus", who is both the producer and the product, generally, of supercomplexity, and, specifically, of the Anthropocene and the Technocene.[137] This "evolved" human

[137] The concept of the "Anthropocene" -from the Greek anthropos, meaning human, and kainos, meaning new- was popularized in the year 2000 by Dutch chemist Paul Crutzen, winner of the Nobel Prize in Chemistry in 1995.

being, having designed, implemented, and expanded artificial intelligence, robotic technologies, genetic engineering, cybernetic integration, and other forms of induced evolution, is transforming both their existential condition and the landscape of the planet. [138]

For the Homo Supercomplexus, the Technocene is profoundly ambivalent: it can enable the development of extremely advanced cognitive skills and capabilities, but it also heightens the potential to inflict significant harm on other human systems and on the natural evolution of the universe and life itself.

Will we be the owners (responsible agents) of evolution or its slaves, bound to technology? Global challenges such as climate change, biodiversity loss, and other ecological crises require understanding and approaches that encompass complex systems at multiple scales. The Homo Supercomplexus must be capable of thinking and acting in ways that acknowledge these critical interdependencies. At the same time, and no less important, the growing cultural diversity and plurality of values and beliefs in globalized societies add yet another layer of complexity. This new homo will need to navigate and reconcile these differences in a constructive and respectful manner.

Ultimately, the present time is the time of the Homo Supercomplexus because it is, in essence, the time of the new, the destabilizing, the unpredictable, the radically emergent.

[138] Morin, in defining the Homo Complexus, highlights a key characteristic of this concept: the ability to manage and live with both internal and external contradictions. He argues that the human being can contain and operate within contradictory logics, which is a fundamental part of their complexity. The Homo Complexus and the Homo Supercomplexus share common roots and spirit, but SK takes a leap forward toward strategic combination, algorithmic operability, and an ethics-creativity that not only understands complexity but also transforms and inhabits it in a playful and conscious way.

The future resists all calculation and planning. It opens a field of challenging alternatives. That is why the SK, through this metaphorical anthropological figure, proposes an attitude of enthusiasm to face the present and confront the future, an attitude nourished by subjective potential, but above all, by the values that emerge from relationality, from social encounters, shared stories, and collective symbols.[139]

Free thought becomes a key tool for breaking the cognitive limitations that have shaped our evolution. By liberating the mind from rigid beliefs, thought becomes expansive, capable of exploring new connections. The brain ceases to function solely as a mechanism of defense, becoming instead a true engine of exploration.

The Homo Supercomplexus assumes that the teleology of the cosmos and the intervention of controlling suprasystems are nothing more than manifestations of a desire rooted in the human mind, shaped by limiting beliefs divorced from the facts described by current science. For this reason, it abandons the need for a purpose imposed from outside and instead takes on the responsibility of constructing its own maps of meaning within the intricate network of interactions that constitute it. Its ethics are not based on dogmas or hidden designs, but on the understanding that reality is the result of multiscalar dynamics in which it is itself a node, an agent actively participating in the ongoing dance of Supercomplexity.

The aesthetic ethics of the “cosmonaut” is a metaphor for the traveler who, through the joy of discovery and creativity,

[139] The SK places the human being at the center as the creator and describer of complexity, but also acknowledges their position on the periphery, as a product of the complex systems that precede and surround them. This balance between the centrality and relativity of the human being is a core philosophical stance of SK.

journeys without a fixed or predetermined destination, with an open mind, embracing the experience as an end in itself.

But it is not relativistic or uncontrolled. On the contrary, love and friendship are central: in interaction with others, individual limitations dissolve, ideas multiply, and networks of collective knowledge are built. Love and friendship become a network of mutual support and development, a key to overcoming the limits imposed by evolution. They are a response, a responsibility.

The happiness of the Homo Supercomplexus is not a fixed point or an external goal, but an emergent phenomenon that results from the interaction between identity, relationships, and the systems it engages with. It is the ability to intelligently manage energy flows, combining desire and relationality, expansion and contraction, pleasure and challenge. It is the art of timing and mapping, knowing when to move forward, when to stop, when to say yes and when to say no. But above all, it is an attitude of openness to beauty, knowledge, and connection with the universe, life, and its dreams. The Homo Supercomplexus finds happiness in the balance between their passion for truth, their wonder at nature, and their ability to share experiences with those who resonate with the same horizon. They enjoy the journey, the learning, and the play, finding in every star, every planet, and every shared gaze a new combination to be happy.

Finally, the overcoming of human limitations is an ideal that can be approached through the recognition of our interconnection with the broader systems that surround us. By ceasing to see ourselves as closed and isolated entities and beginning to recognize ourselves as part of a web of interrelated energies, morphologies, and temporalities, we can transcend the limits of our own body and mind. This transcendence does not imply a denial of the human, but an evolution toward a state of being more aware of our relationship with complexity.

The Homo Supercomplexus chooses a new combination: in the face of the ambivalences of total control or abandonment due to despair and fear, it seeks to "keep the ship flying," but to do so as a team.[140] This perspective of the Homo Supercomplexus captures the essence of SK, where uncertainty and the unexpected are not threats, but opportunities to learn, create, and collaborate. As we have already stated, there is no hidden order waiting to be discovered, but a reality that is constantly reconfiguring. Epistemological uncertainty, then, arises from ontological uncertainty.

By placing the human being at the center of a universe full of complexity, yet recognizing the need to navigate it together, SK advocates for a community-based ethic, one of encounter and resilience in the face of the unknown and the threatening. This idea reinforces the fact that complexity is not confronted alone, but in community, where collaboration and shared experience are essential.[141]

The Homo Supercomplexus is the result of a universe that emerges from the interaction between multiple dynamic

[140] Within SK, the philosopher not only reflects on what is, but also on what could be. This includes imagining possible combinations of systems and outcomes, envisioning scenarios that guide responsible decision-making.

[141] For SK, the universe can also be interpreted as a "sauvage" space (in the sense of Lévi-Strauss), a raw, spontaneous, and fearsome universe. In this context, human beings, as complex and conscious systems, seek to "cultivate" that universe through the creation of cultural, scientific, and technological structures that allow them not only to survive longer, but to do so under conditions of greater well-being, adaptability, and balance. This existential process implies transforming the unknown into the known, chaos into understandable behaviors, and nonlinear interactions into systems that can be described, predicted, and intervened upon. However, SK recognizes that Homo Supercomplexus does not seek absolute control, but rather a balance between understanding and respecting the intrinsic dynamics of the cosmos, to "surf the wave" instead of trying to contain it. In doing so, the human becomes a conscious cultivator of both themselves and their systems of contact, understanding that they not only modify the universe, but are also modified by it.

systems, each with its own fluctuations, tensions, and temporary equilibriums. If the universe is autonomous, in the sense that its evolution is not driven by a fixed external cause or predetermined purpose, then the human subject, as part of this same fabric, shares that autonomy. Their consciousness, culture, and decisions are not shaped by a single logic but are emergent configurations of a system in constant reorganization. In this context, the freedom of Homo Supercomplexus is not merely a break from previous determinisms, but the capacity to navigate among multiple interactions, recognizing that each choice, each bond, and each structure they build is another node in the universe's network of interdependence.

This autonomy is not individualistic or isolated, but relational: it is sustained by the intelligence to integrate energy flows, structural morphologies, and temporal connections that allow the subject to redefine and expand themselves based on their systems of contact. Ultimately, the Homo Supercomplexus does not seek to control the world nor to submit to it, but to coexist with its complexity, understand its autonomy, and participate actively in its evolution.

The Homo Supercomplexus combines deep authenticity with vital playfulness and a wise acceptance of finitude. On one hand, it seeks authenticity in a radical sense, as Kierkegaard understood it: fidelity to oneself, to one's own experience, to one's existential truth, without accepting imposed dogmas or ready-made answers. This authenticity is linked to the courage to build meaning from one's own existence, embracing uncertainty. At the same time, it embraces playfulness as an essential attitude: a way of inhabiting the world through play, creativity, and exploration, without becoming trapped in the gravity of totalizing discourses or existential anguish.[142] But there is more: the Homo Supercomplexus does not despair in the face of finitude, in the face of the certainty of death. Without denying the fragility and limits of existence, it chooses to live without despair, with a serene and luminous attitude, accepting that life is a finite game and, precisely because of that, intensely valuable. Finitude does not prevent expansion, but rather gives it meaning, just as energetic interactions may fade but leave morphological traces behind.

In the combination of authenticity, playfulness, and acceptance of finitude lies a profound key to supercomplex freedom: a freedom that is not merely resistance to power or dogma, but a creative, joyful, and deep freedom. The Homo Supercomplexus embodies a post-terminal optimism: a vital festivity that does not deny finitude, but transforms it into a motive for creation, play, and authenticity.

The Homo Supercomplexus represents a new relational and evolutionary ethic, where personal growth is never achieved at the expense of the development of others. Their identity is built on interdependence and collaboration, guided by the principle that the advancement of one system must not mean the regression of another. This ethical expectation does not stem from an imposed external morality, but arises from the deep understanding that in a supercomplex universe, dynamic balance is sustained through shared benefit, the win-win principle.

[142] The vital playfulness of the Homo Supercomplexus is not merely an individual trait, but an essential communal characteristic. Collective play becomes an effective method for addressing complex problems, as it fosters joint creativity, the exchange of perspectives, and the generation of collaborative strategies. Through playful dynamics, the group not only confronts challenges with greater flexibility, but also strengthens bonds and amplifies collective intelligence. In this context, play is not a mere pastime, but a fundamental tool for engaging with complexity through the diversity of approaches and skills.

As a reflective and creative explorer, the Homo Supercomplexus avoids direct intervention that imposes external solutions. Instead, they use specularity to help systems recognize themselves in their complexity, promoting self-diagnosis and self-transformation. They do not seek to direct or control, but to accompany the unfolding of potentialities by recognizing the connections and energy flows that sustain systemic cohesion.

This relational ethic is complemented by a genuine democratic attitude, where diversity is not an obstacle but a resource that enriches collective decisions. The Homo Supercomplexus understands that centralized power tends to stifle creativity and evolution, while open participation and plural dialogue enhance the development of adaptive and transformative strategies.

The Homo Supercomplexus is not only a thinker but also a practitioner: they design algorithms that respect life, create maps that honor diversity, and navigate uncertainty with aesthetic and axiological awareness. While the modern paradigm dreamed of conquering the universe through certainty, the Homo Supercomplexus, like the Taoist sage or the Zen meditator, learns to surf it. Their science does not seek absolute control, but resonance. Their philosophy does not crystallize dogmas, but cultivates questions. And their existence is not a linear race, but a dance between orders and disorders.

Far from the monopolistic logic that concentrates resources and knowledge in a few hands, the Homo Supercomplexus proposes an ethic of coevolution, where each system contributes its uniqueness to a shared fabric of experiences. Personal autonomy does not oppose collective well-being; rather, it is built in harmony with others, recognizing that true human advancement depends on the ability to generate genuine and responsible networks of collaboration.

Ultimately, we combine three metaphors to describe this new anthropology: that of the Homo Supercomplexus, the cosmic astronaut, and the playful primate. The symbolic relationship between them is articulated through different modalities. The first symbol represents the cognitive, ethical, and philosophical dimension of humanity. It is the being who seeks to understand, map, and surf the complexity of the universe, assuming a position of responsibility and wisdom. The second, by contrast, encapsulates the exploratory and relational spirit. It is the traveler who not only navigates the physical cosmos but also the universes of thought, science, and experience. It is the builder of meaning above meaninglessness. The playful primate is the reminder of our biological, instinctive, and creative nature. It recognizes that we are social animals who evolved through play, interaction, and curiosity. This symbol adds a layer of spontaneity and enjoyment of existence.

An educational proposal based on these metaphors would aim to develop relational thinking in participants, encouraging curiosity, creativity, and enjoyment in learning.[143] It would be structured around interdisciplinary activities that integrate complex systems analysis, open-ended exploratory projects, and playful dynamics such as role-playing, simulations, and creative design. This education would value reflective autonomy, the ability to manage uncertainty, collaboration, innovation, the desire to find solutions, and the pleasure of working in teams.

[143] The Homo Supercomplexus recognizes that both thought and action are mediated by a language that is not neutral, but rather charged with intentions and emergent meanings. Adopting a supercomplex perspective on language means continuously questioning concepts and embracing the polyphony of meanings that arise from human communication. This strengthens an aesthetic ethic oriented toward deep understanding and respectful dialogue, which is fundamental in contexts of high social complexity.

The goal would be to form individuals capable of facing the challenges of today's world with ethics, creativity, and enthusiasm, viewing learning as a continuous and transformative process.[144]

For SK, we are a primate that plays, a cosmonaut that explores, and a Homo Supercomplexus that understands. In the crossing of the playful, the cosmic, the complex, and the supercomplex, we find our true humanity, our respect for all forms of life, and also the potential to transform our place in the universe.

What do Democritus, Hypatia of Alexandria, Leonardo da Vinci, Copernicus, Galileo, Mendeleev, Darwin, Marie Curie, Tesla, Einstein, and other transformative figures in history have in common? Three essential characteristics: their divergence from the dominant thinking of their time, a methodology for generating knowledge, and an authentic, personal attitude toward existence. Each of them possessed a matrix.

The Supercomplex Systems Philosophy is the driving philosophy behind the Homo Supercomplexus in constructing this matrix, a unique way of conceiving science, knowledge, and technological development. It arises from the image of an interconnected universe, where diversity emerges from stochastic (random) combinations and imbrications of energy (flows, information), space (structural morphology, relationships), and time (connection, rhythm). Thus, the SK proposes that there are stances toward the universe, life, and learning that can be structured as a matrix.

The guiding questions that organize this mode of thinking and attitude are:

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[144] The SK Community is developing an educational project that extensively details our proposal, adapting it to various modalities.

1. **ENERGY**: How is energy transformed in the universe? What role do we humans occupy, and how do we harness this energy to grow, learn, and fulfill our aspirations? What strategies do I employ to manage, sustain, or amplify my cognitive, emotional, and attitudinal potential? What beliefs and desires drive or constrain me?
2. **SPACE**: What interconnections in the physical, chemical, and biological universe enable a system's survival? Which systems empower my personal projects without compromising my autonomy? When is collaboration advantageous, and when is competition necessary? When should I resist or acquiesce to dominant structures?
3. **TIME**: How long did it take the universe and life to consolidate resilient energy modalities and structures? How can I balance work, satisfaction, and rest to achieve positive outcomes without burnout? What short- and long-term impacts do my actions have on my environment?

Those who begin to think in these terms, applying these questions, cultivating cognitive discipline, and remaining vigilant about their attitudes, will gradually construct a supercomplex matrix. This matrix enables them to rewrite their personal history and the histories of those who share their journey. It elevates their perception of their own capabilities and talents while providing profound and meaningful fulfillment.

Like the great figures of history, they will sustain enthusiasm and creativity, remaining critical, contributing novel modes of thought, and connecting with all facets of reality. They will perceive how every element can synergize with their projects, finding in research, play, and love the essential components for living and sharing their existence with meaningful beings and all forms of life.

Ultimately, this supercomplex matrix invites us not merely to think but, above all, to be: to challenge the structures of power and alienation in our time, to integrate diverse knowledges, and to anticipate possible futures. These figures distinguished themselves not only through their discoveries but through their ability to organize questions, connect the seemingly unrelated, and open new possibilities for understanding and acting upon reality.

The Homo Supercomplexus does not emerge from nothing. Their capacity to navigate the complexity of the universe is nourished by those who, throughout history, dared to think differently. They are the precursors, the visionaries, the insurgents against linear thought, those who carved paths toward new ways of seeing, connecting, and transforming. Each, in their time, shattered prior paradigms and forged conceptual tools that now feed the new supercomplex paradigm.

They saw beyond the visible, united the fragmented, and created meaning where dogma or void once prevailed. Through combinatorial imagination, keen observation, intellectual courage, and sensitivity to the new, they expanded the boundaries of human understanding.

The Homo Supercomplexus recognizes them as symbolic ancestors, a reminder that thinking freely, relating creatively, and acting with aesthetic ethics in the face of the unknown is not eccentricity: it is the fullest expression of inhabiting intelligence.

The supercomplex matrix is the map for navigating complexity without losing oneself, for thinking without ceasing to be, and for creating without forgetting that we are all interconnected.

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