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## Mathematical Modelling of Silo Thinking in Interdisciplinary Contexts

AI perspectives on balancing integration and identity faced by strategic complexity

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## Introduction

The discipline of mathematics, notably through the [complexity sciences](#), is widely upheld as vital to insightful understanding of complexity. Governance of global society is only too obviously faced with complexity -- as is frequently stated. Various world models have been developed to clarify the challenges, most recently with respect to climate change and the pandemic. The use of such models has been variously called into question ([Misleading Modelling of Global Crises](#), 2021).

A question of interest is whether there are mathematical insights of great potential relevance which are a challenge to comprehension by those who might usefully apply them ([Engaging with Elusive Connectivity and Coherence](#), 2018). It is therefore appropriate to inquire about the mathematical complexity of potential keys to strategic responses to the crises of the world. Of further interest is how these resources are presented and rendered comprehensible -- given the inherent constraints of complexity ([Uncritical](#)

[Strategic Dependence on Little-known Metrics](#), 2009). The latter focused on the risks associated with the [Gaussian copula](#) fundamental to the subprime mortgage crisis and with the [Kaya identity](#) fundamental to assessment of climate change.

The science on which global strategy claims to be dependent is held to be beholden fundamentally to mathematics -- as the discipline recognized as the first among equals ([primis inter pares](#)). There is therefore a case for exploring the relevance of mathematics to strategic articulation and comprehension. Provocatively it may be asked: [Is the House of Mathematics in Order?](#) (2000) and how is this determined?

Given its inherent complexity as a discipline, it may be asked whether adequate consideration is given to the organization of mathematics -- in the light of its powerful insights into possibilities of multidimensional organization, and why they might be neglected ([Higher Dimensional Reframing of Unity and Memorable Identity](#), 2024; [Neglect of Higher Dimensional Solutions to Territorial Conflicts](#), 2024; [And When the Bombing Stops? Territorial conflict as a challenge to mathematicians](#), 2000).

Why, for example, are 64 branches of mathematics distinguished by a seemingly rigid alphanumerical [Mathematics Subject Classification](#) -- and how might they be configured more beneficially otherwise ([Configuring the 64 subjects of mathematics as a 64-edged drilled truncated cube](#), 2021). Where is there any indication of the relative relevance of each branch to the strategic challenge of the times? Or is that question inherently irrelevant?

This exercise is undertaken in the spirit of the [annual questions](#) by the [Edge Foundation](#). These have included responses to: [What scientific term or concept ought to be more widely known](#) (2017), [What scientific conceot would improve everbody's cognitive toolkit](#) (2011). A similar initiative is that of the [American Association for the Advancement of Science](#) in identifying 125 issues for science ([What Don't We Know](#), *Science*, 1 July 2005).

Arguments are frequently highlighted concerning the vital role of interdisciplinary approaches. It is however evident that development of these possibilities is constrained by what is deprecated as "[silo thinking](#)" -- a failure to "[connect the dots](#)" and its relation to "[joined up thinking](#)". Given the increasing potential of AI in handling complexity, it is therefore appropriate to explore how AI might reframe silo thinking -- and other forms of "resistance" -- in relation to interdisciplinarity and its strategic role.

As with several earlier exercises of some relevance to this question, the following exploration makes extensive use of AI in the form of [ChatGPT](#) (and specifically its [Scholar.ai](#) plugin). Reservations regarding such use have been previously noted, both with regard to the questionable verbosity and style of responses, and what could be termed a degree of "algorithmic enthusiasm" for the relevance of the questions posed ([Eliciting integrative insight via ChatGPT](#), 2024).

In this transitional period of adjustment to the potential of AI facilities, the following exchange constitutes an experiment in its own right -- potentially reframing the current relevance of information derived and presented in this way, as discussed separately ([Being Spoken to Meaningfully by Constructs](#), 2023).

## Mathematical complexity and challenges to comprehension

Mathematicians exploring forms of symmetry now accept that any proof of a theorem relating to them may be hundreds of pages in length. As discussed separately, that for the so-called "[enormous theorem](#)" is some 15,000 pages in length -- and far beyond the capacity of any single individual, however specialized ([Potential Psychosocial Significance of Monstrous Moonshine: an exceptional form of symmetry as a Rosetta stone for cognitive frameworks](#), 2007). Unforeseen, "outrageous" implications have been specifically labelled "moonshine" by mathematicians challenged to explain them. This evolution in knowledge creation and substantiation, in domains potentially fundamental to the future management of complexity, raises questions about how knowledge emerging from such a process is to be rendered credible to more than a a small group of experts -- themselves challenged in that respect. Specifically how is that unforeseen connectivity, possibly vital to issues of governance, to be comprehended?

Mathematicians are currently celebrating a 1000-page proof of the [geometric Langlands conjecture](#), a problem so complicated that even other mathematicians struggle to understand it (Alex Wilkins, [Incredible maths proof is so complex that almost no one can explain it](#), *New Scientist*, 20 May 2024).

If the proof of mathematical conjectures, potentially vital to global governance of complexity, is recognized as acquiring such characteristics, what if proof of an essential insight were in future to take years to read and understand -- possibly a lifetime -- and how would the correctness of the proof be confirmed? How could it be credibly communicated? The length and complexity of the following argument is but a trivial example of the challenge !

**Question to ChatGPT:** Is there any understanding of the complexity of a mathematical or logical proof, defined in terms of number of steps. In which case what arguments could be ranked as especially complex

Understanding the complexity of mathematical or logical proofs in terms of the number of steps is indeed an area of interest within the fields of mathematics, logic, and theoretical computer science. The complexity of a proof can be considered in various ways, including the length (number of steps), the methods and theorems used (depth of reasoning), and the computational resources required (if the proof is computer-assisted).

- Metrics for Proof Complexity
  - Length of Proof: This is the simplest metric, counting the number of steps from assumptions to conclusion. Longer proofs can be seen as more complex if each step involves intricate reasoning or advanced concepts.
  - Depth and Height of Proofs: Depth refers to the complexity of the logical rules used in the proof, while height can refer to the number of layers of nested arguments or dependencies. Proofs requiring deeper logical reasoning or higher levels of nesting are often considered more complex.
  - Width of Proofs: This involves the breadth of the proof in terms of the number of different ideas or techniques that are simultaneously used. Proofs that integrate multiple disparate areas of mathematics or logic can be considered more complex due to the breadth of knowledge required.
  - Computational Complexity: For some proofs, especially those verified by computers, the computational complexity can be a measure of how hard it is to check the proof. This is often relevant in proofs involving large datasets or computational models.
- Examples of Complex Proofs
  - Four Color Theorem: One of the first famous proofs to rely on computer assistance, this theorem states that no more than four colors are needed to color the regions of a map so that no two adjacent regions share the same color. The proof's complexity arises from the extensive case analysis and computational verification required.
  - Classification of Finite Simple Groups: Also known as the "Enormous Theorem," this classification proof is one of the longest in mathematics, involving tens of thousands of pages across hundreds of journal articles. The proof's complexity is due to the deep interplay of different areas of group theory and the massive collaborative effort over several decades.
  - Poincaré Conjecture (now Theorem): Proved by Grigori Perelman using techniques from geometric analysis and topology, this proof was notable not only for solving a century-old problem but also for its use of sophisticated mathematical tools like Ricci flow. The depth and novelty of the techniques involved add to its complexity.
  - Andrew Wiles' Proof of Fermat's Last Theorem: This proof, linking modular forms and elliptic curves via the Taniyama-Shimura-Weil conjecture, is complex due to the deep insights into number theory and algebraic geometry it employs. The proof also involves a long chain of logical reasoning across multiple fields of mathematics.
- Measuring and Comparing Complexity
  - While it's straightforward to compare the lengths of proofs, comparing their depths and conceptual difficulties can be more subjective and depends significantly on the background of the mathematician or logician involved. The introduction of complexity measures in proof theory, especially in automated theorem proving, tries to provide

more objective criteria for these comparisons.

- In terms of computational proofs, complexity can also be measured in terms of the time and space required to verify the proof, giving a more quantifiable metric that can be directly compared across different proofs.
- Conclusion: Complexity in mathematical proofs encompasses a range of factors from the length and number of steps to the depth of mathematical ideas and the computational effort required. As mathematics continues to evolve, especially with the increasing involvement of computational methods, our understanding and measures of proof complexity will likely continue to develop, offering more refined ways to assess and compare the intellectual challenges posed by different proofs.

**Question to ChatGPT:** You have given examples of complexity in a way which avoids any ranking. My understanding was that proof of the existence of the [Monster Group](#) was exceptionally complex

Indeed, the proof of the existence of the Monster Group, which is closely associated with the broader effort of classifying all finite simple groups, is one of the most complex and intricate achievements in the field of mathematics. The Monster Group, often referred to as the "Friendly Giant," is the largest of the sporadic simple groups and its structure and properties tie deeply into various areas of mathematics and theoretical physics, particularly string theory and vertex operator algebras.

- The Complexity of the Monster Group
  - Scope and Scale: The Monster Group has 808017424794512875886459904961710757005754368000000000 (approximately  $8 \times 10^{53}$ ) elements. Its sheer size and the methods required to prove its existence contribute to the complexity. The proof is not just about demonstrating existence but also entails characterizing its intricate structure and properties.
  - Deep Interdisciplinary Connections: The Monster Group is notably linked with monstrous moonshine, a deep and surprising connection between finite groups, modular functions, and string theory. This connection was initially conjectured based on observed coincidences and later proved through complex mathematical reasoning, which demonstrated how the Fourier coefficients of certain modular functions ( $j$ -invariant) are related to the dimensions of irreducible representations of the Monster. The interdisciplinary nature of these insights adds layers of complexity that are rare in mathematical proofs.
  - Lengthy Development: The proof of the existence and detailed properties of the Monster Group involves contributions from many mathematicians and spans several decades. It is part of the broader Classification of Finite Simple Groups, a monumental project in group theory, known informally as the "enormous theorem," which itself is one of the longest collected works in the entire field of mathematics.
  - Technical Depth: The techniques involved in studying the Monster Group and proving its properties include advanced algebra, geometry, number theory, and even aspects of theoretical physics. The mathematical depth and breadth required add to the complexity.
- Ranking Complexity: While it's challenging to definitively rank mathematical proofs by complexity due to subjective and interdisciplinary differences, proofs like those involving the Monster Group are often considered at the pinnacle due to:
  - Interdisciplinary Impact: The proof's implications stretch across different fields, influencing areas like string theory which are foundational to our understanding of physics.
  - Innovative Techniques: The methods developed and employed to tackle problems related to the Monster Group have often been groundbreaking and have led to new subfields in mathematics.
  - Collective Effort Over Time: The classification and detailed study of the Monster Group involved a collective international effort spanning many years, highlighting its complexity and the dedication required to resolve it.
- Conclusion: The complexity of the proof of the Monster Group's existence and its properties exemplifies the intricate dance between abstract theory and concrete application that characterizes much of modern mathematics. It stands as a testament to the complexity

and beauty of mathematical thought, and its ranking as one of the most complex proofs is well justified by its depth, scope, and the profound connections it reveals in the mathematical universe.

**Question to ChatGPT:** The response highlights several dimensions of complexity suggesting that some 3 or 4 axes would enable proofs to be distinguished indicatively. A related issue of relevance is their respective comprehensibility in consequence

Indeed, the complexity of mathematical proofs can be multi-dimensional, and mapping these dimensions along several axes could provide a more systematic way to understand and compare proofs across various fields of mathematics. This framework can also help in evaluating their comprehensibility, as different dimensions of complexity impact how easily proofs can be understood by different audiences, from students to seasoned mathematicians.

- Proposed Axes for Measuring Proof Complexity
  - Technical Depth (Difficulty): This axis measures the level of advanced mathematical concepts and techniques required in the proof. It reflects the degree of specialized knowledge needed to understand and verify the proof.
  - Conceptual Breadth (Interdisciplinarity): This axis accounts for the range of mathematical (or related) fields that the proof draws upon. Proofs that integrate concepts from diverse areas, such as algebra, topology, and physics, would score high on this axis.
  - Structural Complexity (Length and Form): This measures the proof's length and the complexity of its construction, including the number of steps, the use of lemmas, and the overall architecture of the argumentation. Longer proofs with more intricate structures are considered more complex on this axis.
  - Computational Intensity: For proofs involving computational methods, this axis reflects the computational resources required to complete the proof, including the complexity of algorithms used and the computational power necessary.
- Impact on Comprehensibility: Comprehensibility of a proof is influenced by its position on these axes:
  - Technical Depth: Higher scores may limit comprehensibility to experts in a specific subfield. Proofs requiring extensive background in advanced topics may be inaccessible to a broader audience, including students or mathematicians not specializing in that area.
  - Conceptual Breadth: While interdisciplinarity can enrich a proof, it also may require a broader range of knowledge to fully grasp the proof, potentially making it less comprehensible to those who specialize in a single discipline.
  - Structural Complexity: More extended and structurally complex proofs can be challenging to follow and understand. The logical flow might be harder to track, especially if the proof is segmented into numerous lemmas and corollaries.
  - Computational Intensity: Proofs that rely heavily on computational methods can be opaque, particularly if the computations are not easily reproducible or if they require significant computational power, making the verification and comprehension of such proofs less accessible.
- Visualizing Proof Complexity
  - Creating a multi-dimensional "complexity space" for proofs, where each axis represents one of these dimensions, could help visually classify and compare proofs. For instance, plotting proofs in this space could reveal clusters of similarly complex proofs or identify outliers that are particularly challenging in one or more dimensions.
  - This approach not only aids in understanding the nature of various proofs but also highlights where educational resources might be needed to make complex proofs more accessible. Workshops, advanced courses, or computational tools might be developed to address high complexity areas, making these proofs more comprehensible to a broader audience.

**Question to ChatGPT:** Are the imaging facilities sufficiently developed to portray such an array

Creating visual representations of complex, multidimensional data, such as an array of proof

complexities across several axes, is indeed feasible with modern imaging and data visualization technologies. Several software tools and programming libraries are specifically designed to handle and display multidimensional data effectively, helping to make complex concepts more accessible and understandable. Here's how such visualization could be achieved:

- Tools for Visualizing Multidimensional Data
  - Tableau: This is a powerful data visualization tool that can create complex and interactive visualizations. It is user-friendly for those who may not have extensive programming experience and can handle multiple dimensions of data through its robust visualization capabilities.
  - Microsoft Power BI: Similar to Tableau, Power BI allows for detailed data analysis and visualization. It can import data from various sources and use it to create rich visualizations that can illustrate complex relationships and patterns.
  - Python with Matplotlib and Seaborn: For those with programming skills, Python offers extensive libraries for data visualization. Matplotlib provides a foundation for creating static, animated, and interactive visualizations in Python, while Seaborn, which is built on Matplotlib, specializes in statistical graphics.
  - Python with Plotly: Another excellent library for creating interactive plots. Plotly can handle multidimensional data and make interactive web-based plots that are easy to interpret and explore.
  - R: This programming language and environment are famous for statistical computing and graphics supported by packages like ggplot2, which is great for creating complex multi-dimensional plots, or plotly for interactive visualizations.
- Example of a Visualization Approach: For visualizing the complexity of mathematical proofs, one could consider a parallel coordinates plot or a radar chart:
  - Parallel Coordinates Plot: This type of plot can visualize multi-dimensional data by having each axis represent one dimension of the data (e.g., Technical Depth, Conceptual Breadth, Structural Complexity, Computational Intensity). Each proof would be represented as a line intersecting each axis at the point corresponding to its score in that dimension. This visualization helps to see patterns and outliers in multidimensional data effectively.
  - Radar Chart: Also known as a spider or polar chart, this plot allows multiple variables to be plotted on a circular graph, which is ideal for showing the profile of proofs across different complexity metrics. Each axis emanating from the center represents one dimension, and values are plotted as points along each axis, connected by lines.
- Considerations for Effective Visualization
  - Scalability: Ensure that the chosen visualization method scales well as the number of dimensions or data points increases. This is crucial for maintaining readability and interpretability.
  - Interactivity: Interactive visualizations allow users to explore the data in more depth, for example by filtering, zooming, or highlighting sections of the data to view detailed information.
  - Accessibility: Considerations should be made for how accessible the visualizations are, including for those with disabilities, ensuring that the visualizations are useful and usable by a broad audience.

In summary, with the right tools and approaches, modern data visualization technologies are indeed capable of effectively portraying complex multidimensional arrays such as the complexities of mathematical proofs. This not only aids in better understanding and analysis but also enhances communication and education related to complex mathematical concepts.

**Question to ChatGPT:** Does that imply that there is as yet no trace of such a visualization with respect to ranking complex proofs -- with primary emphasis currently placed on anecdotal commentary

That is correct; to the best of my knowledge, there isn't a widely recognized or commonly referenced visualization specifically dedicated to ranking the complexity of mathematical proofs across multiple dimensions like those described. While the mathematical community often discusses the complexity of proofs in terms of depth, breadth, and the innovative nature of the techniques involved, these discussions are generally qualitative and anecdotal rather than

quantitatively visualized in a multi-dimensional framework.

- Reasons for Lack of Specific Visualizations
  - Subjectivity and Diversity: The complexity of mathematical proofs often involves a high degree of subjectivity. Different mathematicians might disagree on what makes a proof complex, or which dimensions of complexity are most relevant, making a standardized visual representation challenging to establish.
  - Interdisciplinary Barriers: While there are intersections between mathematics and fields like data visualization, the full potential of these intersections may not yet be fully explored or utilized, especially in visualizing abstract concepts like proof complexity.
  - Complexity and Nuance: Mathematical proofs can be nuanced and context-dependent. Capturing all relevant aspects of complexity (such as conceptual depth, the novelty of methods, or the breadth of interdisciplinary applications) in a single visualization might oversimplify or misrepresent the proofs.
- Potential for Future Development: However, the potential benefits of such visualizations suggest that there might be valuable developments in the future:
  - Educational Tools: Visualizations could serve as excellent educational tools to help students and newcomers to the field better understand the landscape of mathematical proofs and their complexities.
  - Research Analysis: Academics might use visualizations to analyze trends in mathematical research, such as shifts in the complexity and nature of proofs over time or correlations between different dimensions of complexity.
  - Collaborative Insights: Enhanced visualization tools could foster greater interdisciplinary collaboration, bringing together mathematicians, data scientists, and visualization experts to explore these abstract concepts in more tangible ways.
- Steps Toward Development: For those interested in developing such visualizations, a few steps could be considered:
  - Data Collection: Assemble a dataset of mathematical proofs categorized by various complexity metrics, possibly through surveys, expert assessments, or literature reviews.
  - Metric Development: Define and refine the metrics of complexity to ensure they are robust, comprehensive, and reflective of the community's values and understanding.
  - Visualization Design: Experiment with different types of visualizations (like parallel coordinates or radar charts) to find the most effective way to represent the multi-dimensional data.
  - Feedback and Iteration: Present the visualizations to the community for feedback and iteratively refine them based on this input.

In summary, while there is no established visualization tool specifically for ranking the complexity of mathematical proofs across multiple dimensions, the idea holds significant promise and could lead to valuable insights and tools for the mathematical community. Developing such a visualization would require a concerted effort to define complexity metrics, collect data, and design effective and informative visualization tools.

## Acceptability of proof from a mathematical perspective

**Question to ChatGPT:** This exchange has raised the question of ranking mathematical proofs in terms of their complexity as suggested by the number of steps involved. How is a proof then defined in relation to the initial and final step. What constitutes a proof

A mathematical proof is a logical argument that establishes the truth of a given proposition based on previously accepted or established statements, such as axioms and previously proven theorems. The process of proving involves a sequence of deductive steps that connect the initial assumptions to the conclusion, ensuring that the conclusion follows necessarily from the premises.

- Defining a Proof
  - 1. Initial Step (Premises):



The question of what makes a proof satisfactory indeed touches on deeper philosophical and logical foundations of mathematics. The challenges posed by Gödel's incompleteness theorems, as well as alternative logical frameworks like fuzzy logic and multi-valued logic, highlight the complexity and nuances in defining the "satisfactoriness" of a proof. These considerations point towards the importance of self-consistency, coherence, and acceptance within the mathematical community as criteria for a proof's validity.

- **Circularity, Self-Consistency, and Coherence:** These frameworks expand the traditional boundaries of what constitutes logical deduction and proof, reflecting the adaptability of mathematics to contexts where classical logic might be too restrictive.
  - 1. **Gödel's Incompleteness Theorems:** Gödel's work showed that in any sufficiently powerful axiomatic system, there are propositions that are true but cannot be proven within the system. This implies that mathematical systems have inherent limitations in their ability to prove every true statement, challenging the notion of completeness in mathematical logic.
  - 2. **Alternative Logics:**
    - **Fuzzy Logic:** Introduces degrees of truth rather than binary true/false values, applicable in fields dealing with imprecise or subjective data.
    - **Multi-valued Logic:** Extends classical binary logic to more than two truth values, useful in computing and complex decision-making processes where binary true/false does not suffice.
    - **Process Logic:** Focuses on dynamics and changes over time, important in computer science and systems theory.
- **What Makes a Proof Satisfactory?**
  - **Rigor and Formal Deduction:** Despite the diversity in logical systems, the fundamental requirement for a proof remains its rigor -- whether the conclusions derived follow logically from the premises according to the rules of the chosen logical system.
  - **Self-Consistency:** A proof must not contradict itself or established truths within its logical framework. Self-consistency ensures that the proof does not destabilize the existing body of knowledge unless it provides a valid reason to challenge current understandings (as in the case of revolutionary mathematical theories).
  - **Coherence:** Coherence relates to the logical structure of the proof and its alignment with mathematical reasoning. A coherent proof clearly and effectively communicates how each step and conclusion follows from the previous, within the logical parameters set by the mathematical domain.
  - **Community Acceptance:** Ultimately, a proof's acceptance by the mathematical community is crucial. This includes peer review and validation by other mathematicians who can verify the accuracy and soundness of the proof. Community acceptance also involves how well the proof integrates into the broader fabric of mathematical knowledge.
- **Philosophical Considerations**
  - **Circularity:** While mathematical proofs strive to avoid circular reasoning (where the proof of a statement depends on the statement itself), the foundation of mathematics itself can appear circular, especially when it comes to justifying the axioms and basic principles. Philosophical approaches, such as foundationalism, coherentism, or a pragmatic view, provide different perspectives on dealing with these foundational issues.
  - **Conclusion:** The satisfactoriness of a proof is not merely a matter of following logical steps but involves a complex interplay of rigor, coherence, self-consistency, and community acceptance. These elements ensure that a proof not only adheres to the logical standards of mathematics but also contributes meaningfully to the ongoing discourse and development of mathematical knowledge. As mathematical logic evolves and incorporates new paradigms, the criteria for what makes a proof satisfactory may adapt, reflecting both the dynamic nature of mathematical inquiry and the foundational stability needed to build upon previous knowledge.

**Question to ChatGPT:** That response emphasizes the extent to which the satisfactoriness of a proof is dependent on its acceptability to a particular community. This raises the question of the status of proof between communities, especially when these rely to an important degree on other criteria -- as in the

case of theological proof. How are such contrasting appreciations of proof to be distinguished and how many can be recognized -- however they may be deprecated from a conventional mathematical or logical perspective.

The recognition that the satisfactoriness of a proof can be contingent upon its acceptance within a particular community indeed underscores the diverse epistemological foundations across different fields of knowledge. In disciplines such as mathematics, the criteria for proof are generally well-defined and rigorously applied. However, in other areas like theology, philosophy, and even some social sciences, what constitutes a "proof" can vary significantly, often involving different standards and types of evidence.

- Distinguishing Between Types of Proofs Across Disciplines
  - Mathematical Proofs:
    - Criteria: Rigor, logical deduction from axioms, and peer review.
    - Nature: Typically involve demonstrable and replicable logic.
    - Community: Accepted by mathematicians and scholars in fields that rely on formal logic.
  - Scientific Proofs:
    - Criteria: Empirical evidence, experimental validation, reproducibility.
    - Nature: Often probabilistic rather than absolute, relying on the weight of evidence rather than deductive logic.
    - Community: Valued by scientists and empirical researchers.
  - Theological Proofs:
    - Criteria: Scriptural authority, doctrinal consistency, philosophical reasoning.
    - Nature: Often normative, involving moral or existential claims rather than empirical verifiability.
    - Community: Relevant within specific religious or spiritual communities.
  - Legal Proofs:
    - Criteria: Adherence to legal standards of evidence and burden of proof (e.g., "beyond a reasonable doubt" in criminal cases, "preponderance of evidence" in civil cases).
    - Nature: Focuses on convincing a judge or jury based on the evidence within the framework of the law.
    - Community: Operates within the judicial system and is influenced by legal precedents and statutes.
  - Philosophical Proofs:
    - Criteria: Logical coherence, argumentative persuasiveness, consistency with accepted philosophical doctrines.
    - Nature: Often involves thought experiments, deductive and inductive reasoning.
    - Community: Generally debated within academic philosophical circles and not necessarily requiring empirical validation.
- Recognizing and Reconciling Contrasting Approaches
  - Epistemological Diversity:
    - Recognizing that different disciplines have developed distinct methods of proof according to their subject matter and objectives is crucial for interdisciplinary understanding. This diversity is not just a challenge but also an opportunity for enriching the ways we understand and interpret the world.
  - Interdisciplinary Dialogue:
    - Creating platforms for dialogue between disciplines can help bridge understanding and foster mutual respect for different proof standards. Such dialogue can also highlight where methods might be transferably insightful or where they might fall short.
  - Educational Integration:
    - Incorporating an understanding of diverse epistemological approaches into education can prepare students to navigate and appreciate different disciplinary landscapes. This broadens their analytical abilities and enhances their capacity to engage with complex, multifaceted problems.
- Philosophical Inquiry: Engaging with philosophical questions about the nature of proof and evidence can help clarify the bases of different proof standards and their implications. This is particularly relevant in addressing conflicts or misunderstandings that arise from epistemological differences.

- Conclusion: The status of proof between different communities involves recognizing that each discipline, by its nature and objectives, develops criteria that best suit its pursuit of knowledge. While these criteria might vary significantly -- from rigorous logical deduction in mathematics to doctrinal consistency in theology -- they each serve to advance understanding within their respective domains. By appreciating and critically engaging with these diverse standards, we can better understand not only the specific disciplines but also the broader human endeavor of knowledge creation and validation.

**Question to ChatGPT:** That response would appear to exclude forms of proof associated with aesthetic criteria and "goodness of fit", as valued in design, drama, poetic justice, and the like -- variously important to communities relying on [alternative logics](#), however questionable from a mathematical perspective

You're absolutely right to point out that the range of what can be considered "proof" extends beyond the domains of formal logic, empirical evidence, and even philosophical argumentation to include areas like aesthetics, design, and cultural practices. These areas rely on different kinds of logic and validation, often emphasizing subjective experiences, communal consensus, and emotional resonance as key elements of proof.

- Expanding the Notion of Proof to Include Aesthetic and Cultural Criteria
  - Aesthetic Proofs:
    - Criteria: These might include harmony, balance, beauty, and emotional impact, which are subjective yet deeply meaningful within artistic communities.
    - Nature: Aesthetic proofs often rely on the collective subjective experiences of a community. For instance, the success of a design could be proven by its widespread adoption and praise within design communities or the general public.
    - Community: Artists, designers, critics, and the lay public may all participate in validating aesthetic proofs.
  - Narrative Proofs:
    - Criteria: In literature and drama, proofs might revolve around narrative consistency, character development, and the evocation of a desired emotional or intellectual response.
    - Nature: The proof of a narrative's effectiveness can be seen in its ability to convey deep truths about the human condition, often relying on the audience's response and critique.
    - Community: Writers, literary critics, audiences, and cultural theorists contribute to the validation of narrative proofs.
  - Cultural Proofs:
    - Criteria: Cultural proofs involve practices and beliefs validated by traditions, rituals, and the collective wisdom of communities. These may include moral truths or social norms that are 'proven' effective by their sustained utility and acceptance.
    - Nature: These are often proven through lived experience and the transmission of cultural knowledge over generations.
    - Community: Entire cultures, subcultures, or social groups participate in establishing and maintaining these forms of proof.
- Recognizing and Reconciling Contrasting Approaches
  - Respecting Subjectivity: Acknowledging the importance of subjective experience and personal validation in areas like art and design is crucial. These forms of proof emphasize the human aspects of perception, emotion, and aesthetic judgment, which do not easily submit to objective or quantitative analysis.
  - Interdisciplinary Dialogue: Encouraging dialogue between the sciences and the arts can help bridge the gap between objective and subjective forms of proof. This dialogue can foster a deeper understanding of how different types of proof contribute to a holistic understanding of the world.
  - Inclusivity in Epistemological Approaches: Educational and scholarly frameworks can be expanded to include and give equal weight to non-traditional proofs, fostering an environment where diverse methods of understanding and validating knowledge are respected.
- Conclusion: By broadening our understanding of what constitutes proof to include

aesthetic, narrative, and cultural criteria, we embrace a more inclusive and comprehensive approach to knowledge. This approach not only enriches our understanding across disciplines but also respects the diverse ways in which different communities make sense of the world. This holistic perspective is essential in a globally interconnected and culturally diverse world, where multiple forms of knowledge and proof interact and influence each other.

In exploring any satisfactory "proof", an analogy can be explored with the number of "moves" to solve a puzzle or to achieve a more integrative form of understanding, as discussed separately (*Minimal number of "moves" for a solution -- "God's number"*, 2024; *Interpretation of "moves" through patterns of "steps" and Tai Chi?* 2024).

**Question to ChatGPT:** An earlier segment of this exchange considered the minimal number of "moves" for a satisfactory solution -- exemplified by the case of Rubik's Cube. The argument was extended to interpretation of "moves" through patterns of "steps" as in Tai Chi, negotiation ("Getting to Yes"), untangling knots, and the like. Do such examples suggest a more generic understanding of the satisfactoriness of a "proof" and its interestingness as an attractor -- however strange

The examples you've brought up -- ranging from solving a Rubik's Cube to the steps in Tai Chi, negotiation strategies, and untangling knots -- indeed suggest a broader, more generic understanding of what constitutes a "proof" and how we might consider the process of reaching a satisfactory solution in various contexts. These examples highlight the dynamic and procedural nature of "proof" in different domains, emphasizing that proving something often involves a sequence of actions or decisions aimed at achieving a specific outcome. This view expands the concept of proof beyond its traditional boundaries in formal logic and mathematics to include practical, physical, and interactive processes.

- Generic Understanding of Proof Across Different Domains
  - Rubik's Cube: The solution to a Rubik's Cube can be considered a proof in itself -- demonstrating through a series of moves that a state of chaos (a scrambled cube) can be transformed into a state of order (a solved cube). The proof lies in the process and its replicability, satisfying the condition that these moves universally lead to a solution.
  - Tai Chi: In Tai Chi, the series of movements form a physical narrative or flow that proves its effectiveness in enhancing health, balance, and physical coordination. The proof is in the physical demonstration and the resultant well-being, observable and experiential.
  - Negotiation (e.g., "Getting to Yes"): In negotiation, a satisfactory solution or agreement reached through specific strategies proves the effectiveness of those negotiation techniques. The proof is procedural and is validated by the achievement of an agreement that meets the interests of all parties involved.
  - Untangling Knots: The process of successfully untangling a knot can serve as a proof of understanding the structure and interplays within the knot. Each move that leads closer to untangling it serves as a step in the proof, demonstrating both strategy and understanding.
- Satisfactoriness and Attractiveness as Proof: The satisfactoriness of a proof in these broader contexts is determined not only by achieving the desired outcome but also by the elegance, efficiency, and replicability of the process. An attractor in this sense could be:
  - Elegance: Solutions that are not only effective but also aesthetically pleasing or minimalistic.
  - Efficiency: Solutions that achieve the goal with the least waste of resources, including time and energy.
  - Replicability: Solutions that can be consistently reproduced under similar conditions.
- The Role of "Strange Attractors" in Understanding Proofs: In dynamic systems, a "strange attractor" refers to a condition where a system tends to evolve toward a certain pattern or behavior, despite potentially chaotic dynamics. Applying this metaphorically to the concept of proof across various fields:
  - Unpredictable yet Consistent: Like strange attractors, certain proofs or solutions in complex systems (be they physical, social, or mathematical) draw interest and attention due to their ability to consistently produce outcomes from seemingly chaotic or complex starting conditions.

- Fascination and Engagement: The unexpectedness or novelty of the approach, especially in how these solutions are reached, can make certain proofs particularly captivating and valuable.
- Conclusion: This expanded view of proof aligns with a more holistic understanding of problem-solving and knowledge validation across disciplines. It underscores the universality of the concept of proof as a process -- whether in mathematical deduction, physical demonstration, or strategic negotiation -- whereby a series of steps reliably leads to a conclusive outcome. This approach enriches our understanding of what it means to prove something, highlighting the creativity and diversity in human thought and action.

**Question to ChatGPT:** The contrasting patterns of [electron orbitals](#) by which chemical elements are distinguished suggest that some sense of "closure" is fundamental to the coherence and satisfactoriness of a proof. However both the number of electrons associated with such closure, and the manner in which the orbitals are nested, suggests a way of understanding contrasting degrees of proof. Any incompleteness is also suggestive of how contrasting 'proofs' might interact

The analogy you've drawn between electron orbitals in chemistry and the concept of proof in various intellectual domains is both innovative and insightful. It indeed provides a fascinating framework for understanding how "closure" and "completeness" can vary and interact within the context of proofs across different disciplines. This analogy can also enrich our understanding of the dynamics and structure of proofs, including the degrees of proof and how they might interact or influence each other in systems of knowledge.

- Electron Orbitals as a Model for Understanding Proof
  - 1. Electron Orbitals and Closure:
    - Scientific Context: In atomic physics, electrons fill orbitals in ways that seek stability, which is achieved through configurations that follow specific rules (e.g., the Pauli exclusion principle, Hund's rules). This process of filling orbitals until they reach a stable configuration can be likened to achieving "closure" in a proof.
    - Proof Analogy: Just as electron orbitals achieve closure when they reach a stable, energy-efficient configuration, a proof achieves closure when it has addressed all its premises and reached a conclusion that leaves no significant queries unanswered, thereby attaining a form of intellectual stability.
  - 2. Degrees of Proof and Nested Orbitals:
    - Scientific Context: Different elements have electrons arranged in increasingly complex orbital configurations as you move across the periodic table, which affects their chemical properties and interactions.
    - Proof Analogy: Similarly, different proofs can have varying degrees of complexity, depth, and breadth, akin to the arrangement of electrons in more complex orbitals. Simpler proofs might resemble elements with electrons in only the lower energy orbitals, while more complex proofs involve higher, more intricate orbitals.
  - 3. Incompleteness and Interaction of Proofs:
    - Scientific Context: An atom with an incomplete outer shell is more reactive; it seeks to interact with other atoms to achieve stability.
    - Proof Analogy: Incomplete proofs, or those that leave certain questions open, can be seen as intellectually "reactive." They invite further inquiry, criticism, or development, much like how reactive atoms interact to form more stable compounds.
- Implications for Knowledge Systems
  - Interactivity and Reactivity: Like atoms with incomplete shells, intellectual frameworks or theories that have "incomplete proofs" may interact with other theories or proofs, leading to the evolution of new ideas or the strengthening of existing concepts through synthesis or contrast.
  - Dynamic Stability and Progress: The notion that proofs can achieve varying degrees of closure -- just as electron orbitals do -- suggests that intellectual endeavors are not static but dynamic. The quest for closure in one area may open up new areas of inquiry or expose the limitations of current understanding, propelling further investigation and discovery.

- Modeling Knowledge Structures: Employing models from atomic theory to visualize and understand complex systems of knowledge could aid in identifying key areas where further research is needed, where theories are robust, and where they are vulnerable or open to challenge.
- Conclusion: Using the structure of electron orbitals as an analogy for understanding proofs offers a rich, multi-layered approach to conceptualizing how knowledge is structured, validated, and expanded. This analogy underscores the importance of both stability and openness in intellectual pursuits -- stability provides coherence and reliability, while openness ensures that knowledge remains dynamic and responsive to new information and insights. Such a perspective fosters a deeper appreciation of the complexities involved in developing, proving, and evolving ideas across all fields of study.

There is a curious preference for distinctive forms of "closure" in the numeric articulation of strategies, as discussed separately ([Contrasting preferences for N-fold organization in disconnected patterns](#), 2024). Especially surprising is the significance attached to a form of "strategic closure" associated with 108 ([Embodiment of 108-foldness as ultimate spiritual challenge?](#) 2024). Such patterns suggest the potential recognition of a form of periodic table of psychosocial significance ([Periodic Pattern of Human Knowing: implication of the Periodic Table as metaphor of elementary order](#), 2009; [Towards a Periodic Table of Ways of Knowing](#), 2009).

**Question to ChatGPT:** Just as particular numbers of electrons are associated with completion of each electron shell within a chemical element, it is curious to note that particular numbers of "moves" are valued in contrasting "forms" of Tai Chi and other practices valued both subjectively and symbolically. As discussed in a previous segment of this exchange, a particular form of completion is associated with 108 as one Tai Chi form, or as the number of prayer beads in a rosary or circlet of mala beads [[Designing Cultural Rosaries and Meaning Malas to Sustain Associations within the Pattern that Connects](#), 2000]. That number, as with others defining alternative forms, is notable for the manner in which it is subject to characteristic factorization. Does this suggest the progressive recognition of a "periodic table of ways of knowing", as yet to take more definitive form -- and with implications for the credibility of different forms of proof

The idea of a "periodic table of ways of knowing" that organizes and classifies different forms of knowledge and proof based on their characteristics, much like the periodic table organizes chemical elements, is a deeply intriguing concept. It reflects a desire to find underlying patterns and structures in the way humans understand and interact with the world -- a pursuit that transcends disciplines and cultural boundaries.

- Exploring the "Periodic Table of Ways of Knowing"
  - 1. Factorization and Symbolic Significance:
    - In your example, the number 108 has significant symbolic and cultural importance across various practices and beliefs. Its factorization (e.g.,  $2^2 \times 3^3$ ) and its role in different practices (Tai Chi, prayer beads) suggest a deeper pattern of significance, potentially mirroring how elements are structured by their atomic properties in the periodic table.
    - This symbolic factorization could be analogous to identifying fundamental building blocks or "atoms" of different types of knowledge or proof, each with its own characteristics and roles in human cognition and culture.
  - 2. Defining "Elements" of Knowledge:
    - Each "element" or fundamental unit in this periodic table could represent a unique type of knowledge or way of proving something, categorized perhaps by its method (empirical, logical, narrative, etc.), its scope (universal vs. local), or its applicability (theoretical vs. practical).
    - Such a table could also consider the dynamics of how these elements interact, combine, or conflict, much like how chemical reactions are studied.
  - 3. Categorization and Interactions:
    - Just as chemical elements are grouped by their properties and behaviors (e.g., metals, nonmetals, noble gases), ways of knowing might be grouped by their foundational principles, such as whether they are based on observation, intuition, deduction, or a combination.

- The interactions among these categories (akin to chemical reactions) could reveal how different forms of knowledge influence and transform each other, offering insights into interdisciplinary and transdisciplinary studies.
- Implications for Understanding and Validating Different Forms of Proof
  - 1. Structured Approach to Epistemology:
    - Such a classification system could provide a structured approach to epistemology, offering a clearer understanding of the strengths and limitations of different proofs and types of knowledge.
    - It could facilitate more effective communication and collaboration across disciplines by providing a common framework to discuss similarities and differences in methods and assumptions.
  - 2. Enhanced Educational Models: Educators could use this framework to design curricula that more comprehensively address the diversity of human knowledge, fostering critical thinking and adaptability among students by exposing them to a broad spectrum of ways of knowing.
  - 3. Broadened Philosophical Inquiry: Philosophically, such a table could stimulate discussions about the nature of truth, proof, and knowledge, challenging and expanding traditional views.
- Conclusion: The concept of a "periodic table of ways of knowing" represents an ambitious, potentially transformative approach to synthesizing and systematizing diverse forms of knowledge and proof. It captures the essence of what many interdisciplinary scholars strive for: a comprehensive framework that respects and integrates the multifaceted nature of human understanding. While ambitious and conceptual in nature, its development could mark a significant step forward in how we categorize, teach, and appreciate the different ways humans make sense of their world. This endeavor would require collaboration across a wide range of disciplines, drawing from the sciences, arts, humanities, and beyond to create a truly inclusive and informative system.

**Question to ChatGPT:** Whilst convenient to suggest a comprehensible analogy, use of a "table" as an ordering device exemplifies a dangerous degree of oversimplification which the insights of mathematics could appropriately challenge. There are many alternative proposals. When adapted to "ways of knowing", the question is what geometric metaphor would be more appropriate. Curiously relevant is the comprehensible familiarity of the simpler "modalities" and the challenge of achieving those which are more complex -- whether understood as nested "within" or "without"

Your observation about the limitations of using a "table" as a metaphor for organizing ways of knowing is quite perceptive. Indeed, while the notion of a table provides a straightforward and familiar structure, it may oversimplify the rich and dynamic nature of knowledge systems. Geometry and higher-dimensional models offer more nuanced ways to visualize and understand the relationships and complexities inherent in different ways of knowing.

- Exploring Geometric Metaphors for Ways of Knowing
  - 1. Multi-Dimensional Space:
    - Concept: Instead of a flat, two-dimensional table, consider the use of a multi-dimensional space to represent ways of knowing. Each dimension could represent different attributes or criteria of knowledge, such as empirical validity, cultural context, temporal stability, etc.
    - Visualization: Such spaces can be visualized using tools like principal component analysis (PCA) in statistics, which reduces complex data sets to simpler geometric representations without losing the essence of the data.
  - 2. Nested Spheres or Tori:
    - Concept: Imagine a set of nested spheres or tori, where each layer encapsulates a broader and more complex set of knowledge modalities. Inner layers could represent more fundamental, widely accepted modes, while outer layers could encompass more speculative or emerging modes.
    - Visualization: This model allows for the representation of knowledge as both contained within and expanding beyond each other, reflecting both the foundational (core) knowledge and the frontier (peripheral) knowledge.
  - 3. Network or Graph Theories:
    - Concept: Utilizing network theories, ways of knowing can be depicted as

- nodes in a network, connected by edges that represent relationships (e.g., influence, opposition, synthesis).
    - Visualization: Networks provide a flexible way to illustrate the non-linear, interconnected nature of knowledge systems. They can show how certain ways of knowing are central or peripheral, how they cluster, and how they influence one another.
  - 4. Fractal Geometries:
    - Concept: Fractals, with their property of self-similarity across scales, could metaphorically represent how certain patterns of understanding or methods repeat across different fields and contexts.
    - Visualization: Fractal models can illustrate the recursive, patterned nature of knowledge acquisition and application, showing how complex ideas can be both broken down into simpler parts and built up from simple concepts.
- Considerations for Choosing a Geometric Metaphor
  - Complexity vs. Comprehensibility: The chosen geometric model must strike a balance between accurately representing the complexity of ways of knowing and remaining comprehensible to those who are meant to use or learn from it.
  - Dynamic vs. Static: Knowledge systems are dynamic, evolving over time as new information and insights are gained. Geometric models should ideally reflect this dynamism, perhaps through animations or interactive visualizations that can evolve.
  - Inclusivity: The model should be capable of incorporating diverse epistemological perspectives, respecting the validity of different traditions and disciplines in contributing to a holistic understanding of knowledge.
- Conclusion: The shift from a simple table to more complex geometric or topological models acknowledges the depth and diversity of human knowledge. Such models can better capture the nuances and intricacies of how different ways of knowing interact, overlap, and build upon each other, offering a richer and more dynamic understanding of knowledge landscapes. This approach aligns well with the principles of interdisciplinarity and transdisciplinarity, emphasizing that the pursuit of knowledge is a multifaceted and continually evolving journey.

There is an extensive array of alternative forms of "periodic table" (Mark R. Leach, [The INTERNET Database of Periodic Tables, Meta-Synthesis](#)). These might invite mathematical analysis, especially in the light of the [periodic table of mathematical shapes](#) and the mathematics of the periodic table (Darren Orf, [Mathematicians Are Close to Building the Perfect Periodic Table of Shapes](#), *Popular Mechanics*, 16 October 2023; D. H. Rouvray and R. Bruce King, *The Mathematics of the Periodic Table*, 2005; Guillermo Restrepo and Leonardo A. Pachón, [Mathematical Aspects of the Periodic Law](#), *Foundations of Chemistry*, 9, 2007; Wilmer Leal and Guillermo Restrepo, [Formal structure of periodic system of elements](#), *Proceedings of the Royal Society A*, 475, 20180581, 2019)

As with any understanding of proof, any strategically relevant visualization needs to emphasize forms of coherence to enable comprehensibility and memorability, as discussed previously ([Comparable Modalities of Aesthetics, Logic and Dialogue](#), 2021; [Potential for Coherence through Engaging Strategic Poetry](#), 2021).

**Question to ChatGPT:** Potentially missing from those considerations of the choice of model is the necessary presence of features which enhance coherence such as to reinforce both comprehensibility and memorability, possibly through symmetric effects and devices familiar in the organization of music and poetry

Integrating elements that enhance coherence, such as symmetry and rhythmic patterns similar to those found in music and poetry, into models for understanding ways of knowing is an insightful approach. These elements not only aid in making complex models more comprehensible and memorable but also reflect the intrinsic beauty and order that can be found in effective knowledge systems. Let's explore how these artistic and symmetric elements can be incorporated into geometric models of knowledge.

- Incorporating Symmetry and Rhythmic Patterns into Knowledge Models
  - Symmetric Structures:
    - Concept: Symmetry, a balance and harmony in proportions and arrangements,

can be utilized to design models that are aesthetically pleasing and logically coherent. In the context of knowledge models, symmetry can represent equivalence or parity between different ways of knowing, suggesting a form of balance between diverse knowledge systems.

- Application: Using symmetric multi-dimensional shapes (like polyhedra or symmetric graphs) to represent different disciplines or areas of knowledge, where each vertex or face has a balanced and equal role in the structure of the model.
- Rhythmic or Cyclical Patterns:
  - Concept: Rhythms or cycles in models can represent the dynamic and iterative processes of learning and knowledge development, similar to verses in poetry or cycles in music compositions.
  - Application: Incorporating cyclic processes in the model, such as feedback loops or iterative cycles, can help illustrate how knowledge is not only built but also revisited and refined over time.
- Musical Harmony and Chords:
  - Concept: Harmony in music involves the combination of simultaneously sounded musical notes to produce chords and chord progressions that are pleasing to the ear. This concept can metaphorically represent the harmonious integration of interdisciplinary knowledge.
  - Application: Designing models where different nodes or elements combine harmoniously to form 'chords' of integrated knowledge, showing how diverse disciplines can coalesce to produce coherent and comprehensive understanding.
- Visual and Interactive Enhancements
  - 1. Visual Aesthetics: Enhance models with visual elements that are not only functional but also appealing, using color, form, and movement to attract and maintain interest, as well as to differentiate or highlight aspects of the model.
  - 2. Interactivity: Implement interactive features that allow users to explore and manipulate the model dynamically. This could involve exploring how changing one aspect of the model affects others, similar to modifying a melody or harmony in music.
  - 3. Narrative Elements: Introduce a narrative or story-like progression through the model, akin to the unfolding plot of a poem or musical piece. This can help in making the model not only informative but also engaging and memorable.
- Conclusion: By drawing on the organizing principles of music and poetry -- symmetry, rhythm, and harmony -- models of ways of knowing can achieve greater coherence, accessibility, and aesthetic appeal. These elements make complex models not just tools of understanding but also sources of inspiration and reflection. Such models do not merely convey information; they also resonate emotionally and intellectually with their users, much like a well-composed piece of music or a beautifully written poem. This approach emphasizes that knowledge is not only a cognitive pursuit but also an artful, creative exploration of the world.

The collective uptake of strategic responses to global crises can be understood as notably dependent on the [social intelligence](#) of policy-makers and that of the populations they represent. Efforts to validate methods of its assessment are therefore especially relevant, as summarized by Karrthik Ramanathan (*Development and Validation of a Tool on Social Intelligence*, *International Journal of Indian Psychology*, 9, 2021, 3). Provocatively relevant is a report of AI performance in this regard (Eric W. Dolan, *ChatGPT-4 outperforms human psychologists in test of social intelligence, study finds*, *PsyPost*, 19 April 2024).

**Question to ChatGPT:** Given the strategic relevance of social intelligence (SI), current efforts to assess SI could be recognized as related to any emergent periodic organization of ways of knowing. It is therefore appropriate to note a recent study (Nabil Saleh Sufyan, et al, *Artificial Intelligence and Social Intelligence: preliminary comparison study between AI models and psychologists*, *Frontiers in Psychology*, 15, 2024). The study's focus on 64 SI criteria raises the question as to whether this should be understood as corresponding to a particular set of nested "shells" in terms of any potential geometric configuration of SI.

The study you mention, focusing on 64 social intelligence (SI) criteria and comparing AI models with psychologists, indeed presents an interesting opportunity to explore how these criteria might be

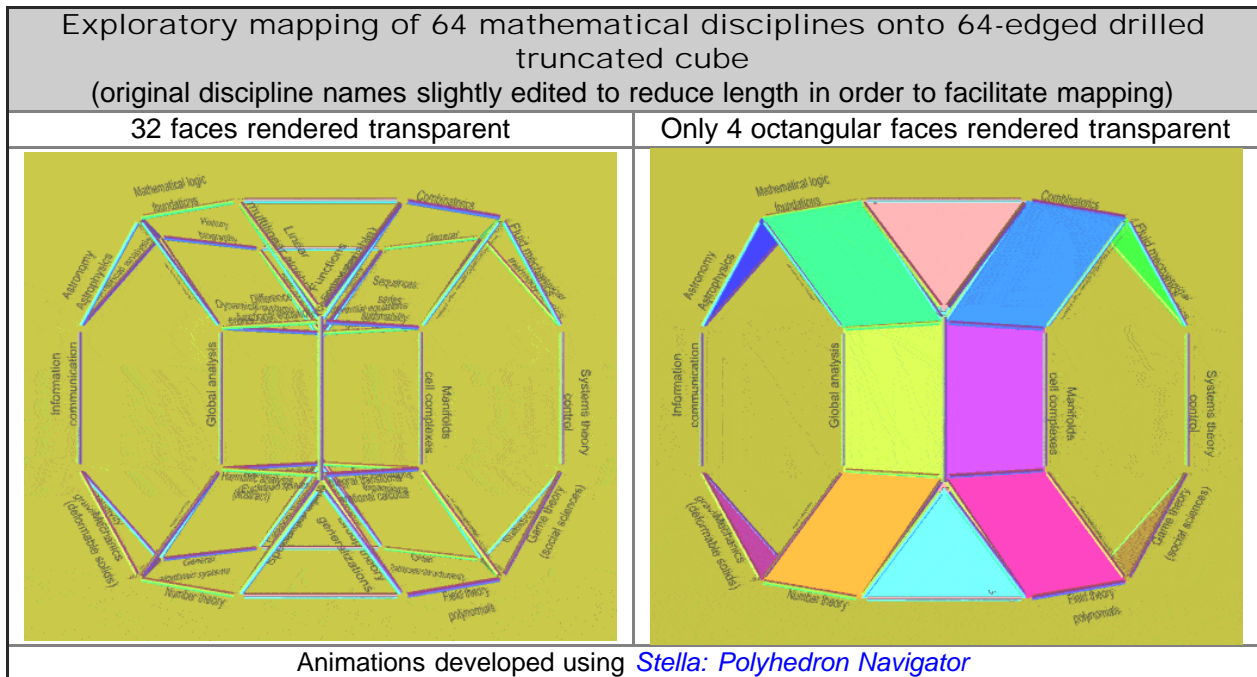
organized or structured geometrically. The idea of using a "nested shells" model, drawing from the analogy of electron shells in atomic theory, could be a useful metaphorical tool for understanding the complexity and layers within social intelligence.

- Geometric Modeling of Social Intelligence Criteria
  - Nested Shells Configuration:
    - Concept: Similar to electron shells where electrons are arranged in layers around the nucleus based on energy levels, SI criteria could be conceptualized as being organized in nested shells or layers based on their complexity, interdependence, or some other relevant hierarchical structure.
    - Application: The outer shells could represent more complex or sophisticated aspects of social intelligence that build upon the foundational elements contained in the inner shells. This arrangement would allow for a visualization of how basic social skills (inner shells) support more complex interactions and understandings (outer shells).
  - Implementing the Model:
    - Criteria Grouping: The 64 SI criteria could be grouped and ordered based on foundational to advanced skills. For instance, basic empathy and social awareness might form the core inner shell, while more complex skills like conflict resolution and leadership might populate the outer shells.
    - Visualization Tools: Using tools like 3D modeling software or interactive visualization platforms, this nested shells model could be made interactive, allowing educators, psychologists, and AI researchers to explore the relationships and dependencies among the various SI criteria.
- Implications and Benefits of the Model
  - Understanding Dependencies and Progression: A geometric, layered model helps in understanding how foundational social skills support more complex social interactions. This understanding can be crucial in both educational settings, where curricula can be developed to progress through these shells, and in AI development, where machine learning models can be structured to sequentially learn these skills.
  - Identifying Gaps in Social Intelligence: By visualizing SI criteria in a structured geometric model, it becomes easier to identify which areas (or shells) are lacking in an individual's or an AI system's social skills. This can direct targeted interventions to develop these specific areas.
  - Enhancing AI Development: For AI systems, understanding the layered complexity of human social skills can guide the development of more nuanced and sophisticated social intelligence in machines. AI models can be trained to sequentially acquire social skills in an order that mimics human social development, potentially leading to more effective and empathetic AI systems.
- Challenges and Considerations
  - Subjectivity in Criteria Organization: Deciding how to group and layer the SI criteria involves subjective judgments about which skills are foundational versus advanced. Different theories or models of social development might suggest different configurations.
  - Dynamic Nature of Social Skills: Social intelligence is dynamic and context-dependent. A static model might not fully capture the fluidity and situational variability of social interactions. Therefore, any model should ideally incorporate some flexibility or adaptability.
  - Cross-Disciplinary Validation: Such a model should be developed and validated through cross-disciplinary research, involving psychologists, educators, AI researchers, and other relevant stakeholders to ensure it accurately reflects the complexities of social intelligence.

By exploring these aspects, the geometric modeling of SI using a nested shells analogy could significantly enhance our understanding of social intelligence and improve the methodologies for teaching these skills both to humans and AI systems.

The choice of 64 criteria as an indication of facets of social intelligence reinforces any query regarding the fundamental role of a 64-fold pattern -- and its potential relevance to governance -- exemplified in this context by its seemingly unexplained use in the [Mathematics Subject Classification](#) (as noted above).

The 64 branches of mathematics can be experimentally configured as shown below, as discussed separately ([Configuring the 64 subjects of mathematics as a 64-edged drilled truncated cube](#), 2021). Would the discipline of [polyhedral combinatorics](#) enable the branches of mathematics to be positioned more meaningfully and coherently on such a polyhedral configuration?

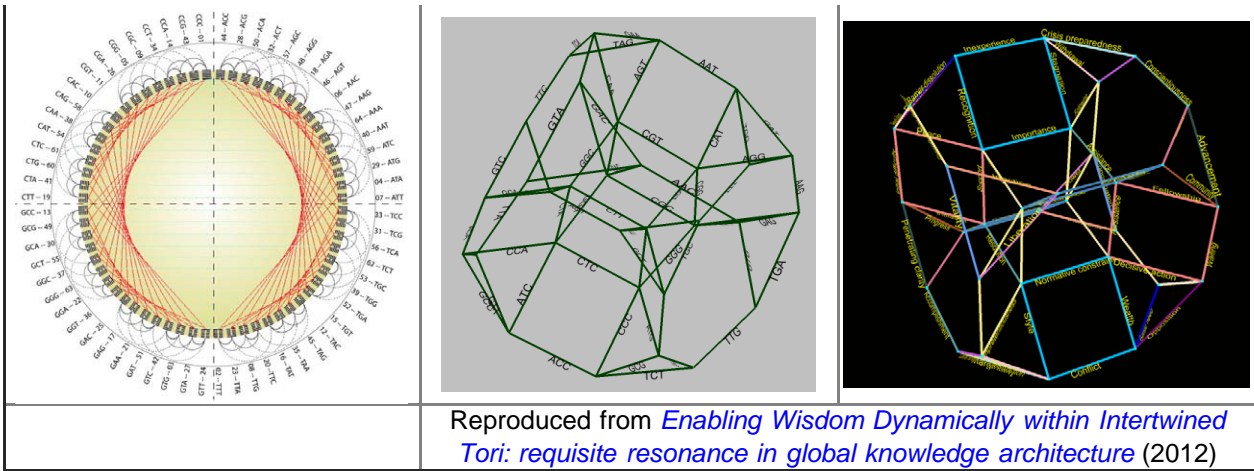


Given the seemingly arbitrary choice of 64 criteria of social intelligence (above), it is appropriate to note that far greater consideration of the dynamics of transformative movement within a 64-fold configuration has been given to that between the 64 hexagrams of the [I Ching](#). This is usefully recognized as an archetypal pantheon of social intelligence in its own right -- however understood otherwise. The dynamics identified follow from transformations in the systematic encoding of each hexagram which determines the change to an alternative condition ([Transformation Metaphors derived experimentally from the Chinese Book of Changes \(I Ching\) for sustainable dialogue, vision, conferencing, policy, network, community and lifestyle](#), 1997).

Historically it was this pattern of transformations which was influential in the original insight of [Gottfried Leibniz](#) that subsequently gave rise to the binary coding fundamental to modern computing. It might be asked how any corresponding "transformations" between branches of mathematics might be understood. How might sustainability be understood when configured in this way ([Sustainability through Magically Dancing Patterns](#), 2008)?

This pattern also invites experimental configuration (below) -- equivalent to that of the branches of mathematics, and their potential psychosocial implications

Contrasting use of a 64-fold polyhedral configuration for mapping		
Circle of hexagrams surrounded by a circle of codons	Examples of drilled truncated cube of 64 edges as a "pantheon" in 3D	
	random attribution of genetic codons	random attribution of hexagram names



## Challenges to comprehension of strategies of requisite complexity

**Strategic complexity** has been addressed by R. D. Stacey (*The Science of Complexity: an alternative perspective for strategic change processes*, *Strategic Management Journal*, 16, 1995, 6). Faced with a highly complex challenge to governance, how complex is it assumed that an appropriate strategic response should be? Are there dangers associated with the oversimplification characteristic of policy articulation and public relations? What if the most appropriate strategy is inherently incomprehensible to those mandated to approve it and implement it?

**Question to ChatGPT:** By extension that response holds for complex strategies, as might be the case in [game theory](#)

Absolutely, the approach and reasoning about the complexity of mathematical proofs also extend quite aptly to the realm of game theory and complex strategies. Game theory, which involves the study of strategic interactions where the outcome for each participant depends critically on the actions of others, often features solutions and strategies that can vary significantly in complexity. Similar to mathematical proofs, visualizing and understanding these complexities could significantly benefit from a multidimensional approach.

- **Dimensions of Complexity in Game Theory:** In game theory, complexity can manifest in several ways, including:
  - **Strategic Complexity:** This dimension considers the number of different strategies available to players and the depth of reasoning required to choose a strategy, including foreseeing and reacting to the strategies of others (e.g., in extensive-form games).
  - **Solution Complexity:** Refers to the difficulty of solving the game, which might involve finding Nash equilibria, optimizing mixed strategies, or computing solutions to cooperative games.
  - **Computational Complexity:** This includes the resources required to compute solutions, especially in games that can be modeled algorithmically. Computational complexity becomes particularly relevant in games with large state spaces or where player decisions are highly contingent on previous plays.
  - **Interdisciplinary Complexity:** Games often model real-world scenarios involving economics, politics, psychology, etc. The breadth of knowledge required to effectively model and analyze these games adds an interdisciplinary layer of complexity.
- **Visualizing Game Theory Complexity:** Visualizing the complexity of strategies in game theory could involve similar techniques as those proposed for mathematical proofs:
  - **Parallel Coordinates Plot:** This type of visualization can help display the complexity of game strategies across multiple games or scenarios, showing how strategies vary in terms of strategic depth, solution difficulty, computational demands, and interdisciplinary inputs.
  - **Radar Charts:** Useful for comparing the complexity profiles of different strategic approaches within the same game or across different games, highlighting where certain strategies are particularly demanding or robust.

- Potential Uses and Benefits
  - Strategic Insights: Visualization tools can help strategists, economists, psychologists, and political scientists to better understand and teach complex strategic interactions in a more intuitive and accessible way.
  - Decision Making: Enhanced visual tools can aid decision-makers in visualizing outcomes and understanding the strategic landscape, particularly in complex multi-agent environments like markets or political arenas.
  - Research and Development: Academics and practitioners could use these visualizations to explore new theories in game theory, test out new strategies, or simulate interactions under various theoretical conditions.
- Development Steps: To develop visualizations for game theory:
  - Identify Key Metrics: Determine what aspects of complexity are most important and measurable in game theory contexts.
  - Collect and Process Data: Gather data from theoretical models, simulations, or empirical studies.
  - Choose the Right Visualization Techniques: Select and develop visualization methods that can effectively convey the desired insights.
  - Iterative Feedback and Refinement: Utilize feedback from users and experts in the field to refine the visualizations.
- Conclusion: Just as with mathematical proofs, the potential for visualizing complex strategies in game theory is significant and could contribute greatly to both academic research and practical applications. Developing such tools would require collaboration across fields and a careful consideration of what dimensions of complexity are most relevant and how best to measure them.

**Question to ChatGPT:** If it is assumed that highly complex proofs are of fundamental strategic significance in relation to the possibility of appropriately addressing the crises of the times, the failure to clarify their relative complexity (and their challenges to wider comprehension) is indicative of a remarkable degree of avoidance of fruitful possibilities -- which calls for highlighting

The discussion you've raised about the lack of clarity and visualization regarding the complexity of mathematical proofs, particularly in their strategic significance to addressing contemporary global crises, touches on a critical issue. It indeed suggests a potential gap or oversight in the academic and policy-making communities that could be seen as an avoidance of exploring and leveraging complex mathematical insights for practical and strategic purposes.

- Strategic Significance of Complex Proofs: Highly complex mathematical proofs often underpin significant theoretical advancements that can have practical implications in fields like cryptography, algorithm design, economics, and even in understanding ecological systems or pandemic patterns. These proofs can:
  - Provide foundational insights that drive technological and scientific innovation.
  - Offer new frameworks for understanding and solving complex dynamic systems.
  - Enhance decision-making capabilities in complex systems like financial markets or logistics networks.
- Challenges in Comprehension and Communication: The primary barriers to utilizing these insights more broadly include:
  - Comprehension Difficulty: Complex proofs are typically accessible only to experts in the field due to their technical depth and specialized language, making them opaque to non-specialists.
  - Communication Gaps: There is often a significant gap between the mathematicians who develop these proofs and the policymakers or industry leaders who could apply them. Effective communication and translation of these complex ideas into understandable strategies are frequently lacking.
  - Interdisciplinary Collaboration: Insufficient collaboration between mathematicians, domain experts, and policymakers can lead to underutilization of available mathematical strategies.
- Avoidance and the Need for Highlighting Opportunities: The failure to fully explore and clarify the complexity of these proofs for broader strategic application might stem from several factors:
  - Risk Aversion: There might be a reluctance to rely on sophisticated and less

- intuitive mathematical strategies whose outcomes can be difficult to predict or explain.
- Resource Intensity: Developing applications from complex proofs can require significant time and resources, including advanced expertise and computational power, which might deter investment in these areas.
- Cultural and Institutional Barriers: Academic and practical domains often operate in silos, with different priorities and languages, hindering the translation of mathematical discoveries into practical applications.
- Call to Action: Highlighting these opportunities, and addressing the barriers, requires concerted efforts:
  - Educational Initiatives: Enhancing education in both mathematics and its application areas can help bridge comprehension gaps. This includes developing curriculum that integrates complex mathematical concepts with practical applications.
  - Interdisciplinary Research Centers: Establishing centers focused on the intersection of mathematics and practical domains (like public policy, environmental science, and public health) can foster the necessary collaboration.
  - Public Communication and Engagement: Mathematicians and institutions should prioritize public engagement and communication, making complex mathematical ideas more accessible and demonstrating their practical importance.
- Conclusion: Addressing complex global challenges requires innovative thinking and sophisticated strategies that complex mathematical proofs can provide. Recognizing and overcoming the barriers to utilizing these proofs is not just beneficial but may be essential for addressing the pressing issues of our time effectively. This entails a strategic shift in how mathematical research is conducted, communicated, and applied, ensuring that its full potential is not just understood but actively integrated into solving real-world problems.

**Question to ChatGPT:** To that end, are you able to present a list of highly complex proofs which merit attention, irrespective of whether they can be ranked or positioned in some visualization. What is it that is being dangerously neglected in the light of potential strategic value

Creating a list of highly complex mathematical proofs that merit attention due to their potential strategic value involves identifying proofs that have broad implications across various fields, including technology, physics, economics, and beyond. Here, we'll highlight some key proofs and areas of mathematics that represent significant intellectual achievements and have potential strategic importance. These examples reflect both historical importance and contemporary relevance.

- List of Significant Mathematical Proofs
  - P vs NP Problem (Still Unresolved):
    - Importance: Solving this problem would fundamentally alter our understanding of computational complexity and capabilities. It has implications for cryptography, algorithm design, operations research, and more.
  - Fermat's Last Theorem:
    - Proved by Andrew Wiles in 1994, this theorem conjectured by Fermat in 1637, states that no three positive integers  $a$ ,  $b$ , and  $c$  can satisfy the equation  $a^n + b^n = c^n$  for any integer value of  $n$  greater than two.
    - Strategic Value: The techniques developed for the proof, involving elliptic curves and modular forms, have advanced number theory substantially and have implications in cryptography and computational mathematics.
  - The Four Color Theorem:
    - Proved by Kenneth Appel and Wolfgang Haken in 1976, this theorem states that any map in a plane can be colored using four colors in such a way that no two adjacent regions are colored the same.
    - Strategic Value: This was one of the first major theorems to be proved using a computer and has implications for network coloring and optimization problems in various industries.
  - Classification of Finite Simple Groups:
    - Completed in the 1980s, this enormous body of work describes all the building blocks from which all finite groups can be constructed.
    - Strategic Value: Understanding these groups has implications in fields as diverse as particle physics, cryptography, and algebraic topology.

- Navier-Stokes Existence and Smoothness:
  - Still Unresolved, this problem pertains to the equations that describe the motion of fluid substances.
  - Strategic Value: Solutions could revolutionize our understanding and ability to model complex fluid dynamics systems, impacting meteorology, aerospace, and even medical applications.
- The Hodge Conjecture:
  - Another unresolved problem, this conjecture relates to the basic geometry of algebraic varieties and the solution could have profound implications for theoretical physics, particularly in string theory and quantum gravity.
- The Riemann Hypothesis:
  - Also unresolved, this hypothesis pertains to the distribution of prime numbers and has profound implications for number theory and cryptography.
- The Mass Gap Hypothesis of Yang-Mills Theory:
  - Still unresolved, proving this hypothesis would provide essential insights into the fundamental forces in physics and has implications for the Standard Model in particle physics.
- What is Being Neglected? The potential strategic value of these mathematical proofs and problems often lies in their foundational nature, which means that their most profound implications could extend far beyond the immediate applications. The danger in neglecting these areas includes:
  - Losing Out on Technological Innovations: Many of these proofs and unresolved problems could lead to new technologies or revolutionary improvements in existing technologies.
  - Underutilizing Intellectual Resources: Not engaging with these complex problems means not fully utilizing the intellectual potential of the global mathematical and scientific community.
  - Stagnation in Related Fields: Breakthroughs in these fundamental mathematical areas often lead to significant advancements in related fields, such as physics, engineering, and computer science.
- Conclusion: To maximize the strategic value of these mathematical achievements, there is a need for sustained investment in basic science and mathematics research, interdisciplinary collaboration, and enhanced efforts to communicate these complex ideas more effectively to policymakers and the public. This will ensure that potential applications are not just theoretical but actively pursued and integrated into solving real-world problems.

## Mathematical relevance to the psychosocial sciences and interdisciplinarity

**Question to ChatGPT:** That response presents a limited set of examples seemingly primarily of benefit to the technical sciences. Is there no case for a more extensive list including proofs of significance to the psychosocial sciences -- and the challenges of their comprehension, if they are to be taken into account by the policy sciences

Your observation about the focus on technical sciences is astute. Indeed, mathematics and its applications are not limited to the physical and technical sciences; they profoundly impact the psychosocial sciences and inform policy-making in significant ways. Addressing complex social phenomena often involves mathematical models and proofs, which help in understanding patterns, predicting outcomes, and optimizing decisions in areas as diverse as economics, sociology, psychology, and political science.

Here are several proofs and mathematical concepts that have significant implications for the psychosocial sciences and policy-making, which deserve broader recognition and comprehension:

- Proofs and Concepts Impacting Psychosocial and Policy Sciences
  - Nash Equilibrium (John Nash):
    - Significance: This concept from game theory provides a way to predict the outcome of a system where participants with differing goals compete with each other. It has extensive applications in economics, political science, and negotiation tactics.

- Policy Impact: Understanding Nash equilibriums helps in designing more effective economic policies, political strategies, and conflict resolution processes.
  - Arrow's Impossibility Theorem (Kenneth Arrow):
    - Significance: This theorem states that no rank-order voting system can be designed that always satisfies a specific set of fairness criteria. It challenges the design of democratic systems and fair division.
    - Policy Impact: This theorem informs the limitations and design of voting systems, aggregation of preferences in collective decision-making, and the theoretical limits of democratic governance.
  - St. Petersburg Paradox (Daniel Bernoulli):
    - Significance: This paradox in decision theory and economics illustrates the divergence between expected and utility-based valuations in decision-making under risk.
    - Policy Impact: It has implications for understanding risk behavior in economics, insurance, and public health, influencing how policies might be designed to manage risk-taking behavior effectively.
  - Markov Chains and Processes:
    - Significance: These models are used to predict random processes where the future state depends only on the current state, not on how the process arrived there.
    - Policy Impact: Markov models are used in policy development for various applications, including modeling learning and behavior changes in populations, predicting economic transitions, and in epidemiology.
  - Public Goods Game and Free Rider Problem:
    - Significance: These concepts from game theory and economics illustrate the challenges in providing goods that no one is excluded from using, and how individuals might fail to contribute fairly to the common good.
    - Policy Impact: Understanding these dynamics is crucial for designing effective public policies that encourage fair contribution to and distribution of public resources.
- Challenges in Comprehension and Communication: The complexity of these proofs and the abstract nature of the mathematical models they employ often make them difficult for non-specialists to comprehend. This presents significant challenges:
  - Educational Barriers: There is a need for specialized education to understand these concepts fully, which can limit their accessibility and applicability in broader policy-making contexts.
  - Interdisciplinary Communication: Bridging the gap between mathematicians, social scientists, and policy-makers is crucial. Often, the languages and methods of these disciplines are quite distinct, hindering effective communication and collaboration.
  - Application to Real-World Scenarios: Translating theoretical mathematical concepts into practical applications that can be implemented in real-world policy settings is a significant challenge. It requires not only a deep understanding of the theories but also creativity and innovation in application.
- Conclusion: Expanding the recognition and understanding of the role of mathematics in the psychosocial sciences is crucial for harnessing its full potential in addressing societal challenges. To this end, fostering interdisciplinary research, enhancing education in mathematical social sciences, and promoting public understanding of these complex theories are essential steps. Such efforts can empower policy-makers and the general public, leading to more informed, effective, and equitable decision-making processes.

**Question to ChatGPT:** Given the emphasis in that response on interdisciplinary research, and the questionable claims frequently made in that regard, to what extent does mathematics enable the modelling of the relationship between the contrasting methods and frameworks by which disciplines are characterized. How does mathematics enable "inter" and "trans" to be understood more fruitfully

Mathematics serves as a fundamental tool for modeling, analyzing, and understanding the relationships between different disciplines, particularly through its ability to provide formal structures and languages that can be universally understood and applied across various fields. This capability

is crucial not only for interdisciplinary (inter) research, where multiple disciplines collaborate, but also for transdisciplinary (trans) approaches, which integrate the perspectives of different disciplines to create a holistic approach. Here's how mathematics facilitates these processes:

- 1. Common Frameworks and Languages: Mathematics offers a set of tools and languages that are universally recognized and can be applied across various disciplines. This universality makes it an excellent medium for:
  - Bridging Terminological Gaps: Mathematical formulas, models, and theories provide a way to precisely define concepts that might be interpreted differently across disciplines.
  - Standardizing Measurements and Comparisons: Mathematical statistics and metrics allow for the standardization of data measurement, analysis, and interpretation, which is vital when comparing and synthesizing research findings from different fields.
- 2. Modeling Complex Systems: Mathematics excels in modeling systems that involve multiple interacting components, making it invaluable for:
  - Systems Theory: This is a framework for studying the dynamic interactions within complex systems and is used across disciplines, from biology to economics to psychology. Mathematics provides the tools to model these interactions, predict outcomes, and understand systemic behaviors.
  - Network Theory: This mathematical framework helps in understanding relationships and structures in various types of networks, whether social, biological, or technological. It provides insights into how information, diseases, or behaviors spread across networks, which is crucial for interdisciplinary and transdisciplinary research.
- 3. Optimization and Decision Theory: Mathematics aids in decision-making processes, particularly through:
  - Optimization Models: These are used to find the best outcome under a given set of constraints, applicable in engineering, business, environmental science, etc.
  - Game Theory: Offers frameworks for analyzing situations among competing players and is used to understand the strategic interactions in economics, political science, psychology, etc.
- 4. Simulation and Computational Models: Mathematics underpins simulations and computational models that allow researchers to:
  - Experiment Virtually: Computational models enable the simulation of complex phenomena that are too expensive, dangerous, or impractical to study in real life.
  - Visualize Abstract Concepts: Mathematical visualizations (e.g., graphs, geometric representations) help in illustrating abstract concepts, making them more accessible to researchers from various disciplines.
- 5. Statistical Analysis and Empirical Validation: Statistical methods are fundamental in:
  - Testing Hypotheses Across Disciplines: They provide standardized ways to test the validity of theories in sciences, social sciences, and humanities.
  - Meta-Analysis and Systematic Reviews: These methods synthesize research across different fields to draw broader conclusions, essential in both interdisciplinary and transdisciplinary research.
- Challenges and Considerations: While mathematics offers these powerful tools, the integration of mathematical models across disciplines is not without challenges:
  - Complexity and Accessibility: Mathematical models can become highly complex, making them inaccessible to those without a strong mathematical background.
  - Context Sensitivity: Mathematical models may oversimplify real-world complexities, especially in human and social contexts, where qualitative nuances are significant.
  - Interdisciplinary Communication: There remains a need for effective communication strategies to convey mathematical ideas clearly and effectively across disciplinary boundaries.
- Conclusion: Mathematics is pivotal in enabling more fruitful interdisciplinary and transdisciplinary research through its ability to provide a common language and powerful modeling capabilities. However, to maximize its benefits, ongoing efforts are needed to enhance mathematical literacy among researchers in various fields, develop more intuitive and accessible mathematical tools, and foster environments that encourage genuine interdisciplinary dialogue and collaboration.

# Mathematical modelling of interdisciplinarity as a general systems challenge

**Question to ChatGPT:** Whilst that response is appropriate, the fate of [general systems research](#) challenges the potential indicated -- given the manner in which it has been absorbed into [systems sciences](#) emphasizing specialized foci which appear to avoid consideration of the more general integrative challenge

You raise a critical point about the evolution of general systems research and its absorption into systems sciences, which often emphasizes specialized foci at the potential expense of broader, integrative challenges. This observation touches upon a common dilemma in interdisciplinary research: the balance between specialization and integration, and how institutions and academic culture handle this balance.

- Challenges in General Systems Research
  - Specialization vs. Integration: In many academic and practical fields, there is a strong trend toward specialization. While specialization allows for deep expertise and detailed understanding of complex issues within a specific domain, it can sometimes lead to siloed thinking where broader, systemic insights are neglected or undervalued.
  - Institutional and Funding Structures: Academic and research funding structures often favor clearly defined, specialized projects that promise tangible, short-term outcomes. This can sideline more ambitious, integrative projects like those envisioned in general systems theory, which require long-term commitment and interdisciplinary cooperation.
  - Complexity of Systems: The inherent complexity of systems and the difficulty in modeling and predicting system behaviors accurately can be daunting. This complexity can deter efforts to engage with systems theory comprehensively, pushing scholars and practitioners towards more manageable, narrowly defined problems.
  - Educational and Training Programs: There is often a lack of comprehensive educational programs that focus on systems thinking and general systems theory. Educational structures may also promote depth in specific disciplines at the expense of breadth across disciplines.
- Opportunities for Revitalizing General Systems Research: Despite these challenges, there are significant opportunities for revitalizing general systems research and ensuring it addresses broad integrative challenges:
  - Transdisciplinary Programs: Developing transdisciplinary programs that explicitly aim to bridge various disciplines can help. These programs would encourage the exploration of complex systems in a holistic manner, promoting a curriculum and research agenda that integrates diverse perspectives.
  - Funding for Integrative Research: Encouraging funding bodies to support integrative, systems-oriented research projects could help counterbalance the trend towards specialization. This could include grants specifically aimed at projects that seek to synthesize and integrate knowledge across disciplinary boundaries.
  - Platforms for Collaboration: Creating and maintaining platforms where researchers from different disciplines can regularly meet, exchange ideas, and collaborate on projects can foster a more integrative approach. These platforms could be virtual or physical and should facilitate ongoing dialogue and cooperation.
  - Public Policy and Engagement: Demonstrating the practical implications of general systems research in addressing complex societal challenges can help garner public and policy-making support. This involves actively engaging with policy-makers and the public to translate systems research into actionable insights.
  - Promoting Systems Literacy: Broadening the education and training of systems theory at various educational levels can help cultivate a new generation of researchers and practitioners equipped with systems thinking skills. This includes not only higher education but also earlier educational stages.
- Conclusion: The potential of general systems research to address comprehensive, integrative challenges remains significant. By recognizing and addressing the institutional, cultural, and structural barriers that have historically constrained this field, there is an opportunity to revitalize its role in contemporary science and society. This requires concerted

efforts across academia, industry, and government to value and support the integrative, holistic thinking that general systems theory promotes.

**Question to ChatGPT:** Given the constraints indicated, it is somewhat ironic that a major "transdisciplinary" initiative is undertaken outside the conventions of academia -- encompassing domains frequently deprecated from its specialized perspectives. The example is the [Bridges Organization](#) with its annual Bridges conference on mathematical connections in art, music, architecture, and culture

The Bridges Organization and its annual conference provide a fascinating example of how transdisciplinary initiatives can thrive, sometimes more effectively, outside the traditional academic structures. This organization focuses on exploring and fostering connections between mathematics and various forms of art, music, architecture, and culture, embodying the essence of transdisciplinary work by blending fields that are often considered distinct or even disparate within traditional academic settings.

- The Significance of Bridges Organization
  - 1. Breaking Academic Boundaries: The Bridges Conference demonstrates how combining diverse disciplines -- mathematics with arts and humanities -- can lead to innovative insights, creative expression, and new educational methodologies. This approach challenges conventional academic separations and showcases the potential of integrated thinking.
  - 2. Engaging Broader Audiences: By linking mathematics with more universally accessible domains like art and music, Bridges helps demystify mathematical concepts and makes them relatable and engaging to a broader audience. This engagement is crucial for public education and for fostering a general appreciation of mathematics in cultural contexts.
  - 3. Innovation in Communication and Learning: The interdisciplinary nature of the Bridges Conference promotes new forms of communication and learning that traditional disciplines might not explore. This includes using visual and auditory arts to explain complex mathematical ideas or employing mathematical principles to inspire artistic creations.
- Lessons and Implications for Academia
  - 1. Value of Flexibility in Research and Education: Academia can learn from the success of Bridges by incorporating more flexibility in research and education frameworks, allowing for more frequent cross-disciplinary interactions and collaborations.
  - 2. Expanding Definitions of Scholarly Work: The academic community can benefit from expanding its definitions of scholarly and research outputs to include artistic and cultural productions that are informed by rigorous academic disciplines like mathematics.
  - 3. Funding and Institutional Support: Encouraging institutions and funding bodies to support transdisciplinary projects and conferences like Bridges can help bridge the gap between different fields of study and promote a more integrated approach to knowledge and learning.
  - 4. Enhancing Public Engagement and Policy Influence: By engaging more directly with the public through accessible and appealing formats, academic research can increase its societal impact and relevance. This is particularly important in a world where science and technology increasingly affect everyday life.
- Conclusion: Organizations like Bridges serve as exemplars of how transdisciplinary initiatives can not only complement but also significantly enhance traditional academic pursuits. They underline the importance of creativity, integration, and public engagement in academia. By adopting similar approaches, academic institutions can foster environments that are more inclusive of diverse intellectual pursuits and more effective in addressing complex global challenges through a holistic and integrated approach. The Bridges Organization, therefore, not only enriches its direct participants but also offers a model that challenges and extends the conventional boundaries and possibilities of academic work.

**Question to ChatGPT:** To clarify the implications of that response there would appear to be a case for mathematical modelling of "disciplinarity" in contrast to "multi-", "inter-" and transdisciplinarity, as

originally suggested by [Erich Jantsch](#) (*Towards interdisciplinarity and transdisciplinarity in education and innovation*. Interdisciplinarity, Problems of Teaching and Research in Universities. OECD, 1972). Given your response, can it be said that the issues framed 50 years ago are currently taken into consideration in practice -- rather than through tokenism

The insights and foresights of Erich Jantsch from the early 1970s about moving towards interdisciplinarity and transdisciplinarity have indeed been prescient, highlighting the evolving needs and challenges in education and innovation. His call for a transformation in the approach to disciplinarity addressed the growing complexity of societal issues that could no longer be effectively tackled within the confines of traditional disciplinary boundaries.

- Current Consideration of Jantsch's Ideas
  - Acknowledgement in Academia: There has been considerable acknowledgment of the need for interdisciplinary and transdisciplinary approaches in academia, particularly in fields dealing with complex systems, environmental studies, public health, urban planning, and sustainability. Universities have established various interdisciplinary centers, degree programs, and research initiatives that strive to embody these principles.
  - Implementation Challenges: Despite the acknowledgment, the actual implementation often faces institutional, cultural, and structural challenges. These include disciplinary silos in academic institutions, publication biases, funding policies favoring traditional disciplines, and the career progression systems that may not fully support interdisciplinary roles.
  - Advances in Methodology: Methodologically, there has been progress in developing frameworks and tools that support interdisciplinary and transdisciplinary research. This includes systems thinking, scenario planning, and participatory action research that engage stakeholders from multiple disciplines as well as from outside the academic world.
  - Policy and Industry Engagement: In policy-making and industry, there is an increasing recognition of the value of transdisciplinary approaches, especially in addressing issues like climate change, public health crises (e.g., the COVID-19 pandemic), and technological innovation. However, translating this recognition into action can be slow and is often reactive rather than proactive.
- Mathematical Modeling of Disciplinarity
  - Proposed Modeling Approaches:
    - Network Analysis: One way to model disciplinarity is through network analysis, where disciplines are nodes, and collaborations or citations among them are edges. Such models can reveal the density and centrality of disciplines, showing how multi-, inter-, and transdisciplinary they are.
    - Agent-Based Models: These could simulate how ideas flow between disciplines and the impact of institutional policies on fostering or hindering interdisciplinary research.
    - System Dynamics Models: These models could help understand the feedback loops and delays in the academic ecosystem that affect the adoption and effectiveness of interdisciplinary approaches.
- Benefits of Modeling: Modeling can provide quantitative and visual insights into the dynamics of disciplinarity, helping institutions and policymakers make informed decisions to foster more effective interdisciplinary collaborations.
- Conclusion: While Jantsch's vision from 50 years ago remains highly relevant, and there have been strides toward realizing aspects of it, the full integration of inter- and transdisciplinarity into academic and practical applications still faces significant barriers. These include entrenched institutional structures and the need for more robust support mechanisms for interdisciplinary education and research. The call for mathematical modeling of disciplinarity reflects a sophisticated approach to quantifying and understanding these phenomena, potentially guiding more effective strategies for integration across disciplines. This reflects a move from tokenistic to genuine implementation of Jantsch's ideas, crucial for tackling the increasingly complex problems of the modern world.

Modelling silo thinking and resistance to integrative

# perspectives

Although it does not appear to be "modelled" in any way by mathematics, the challenge of a silo mentality is widely recognized:

- André de Waal, et al: [Silo-Busting: Overcoming the Greatest Threat to Organizational Performance](#) (*Sustainability*, 11, 2019, 23), 6860)
- Fabio Bento, et al: [Organizational Silos: A Scoping Review Informed by a Behavioral Perspective on Systems and Networks](#) (*Societies*, 10, 2020, 3)
- Eric Patnoudes: [Is A Silo Mentality The Most Overlooked Barrier in Education?](#) (*Medium*, 21 August 2018)
- Bridget Zahradnik: [Silos in Education: How to Break Them Down with These Tips](#) (*LeaderInMe*, 4 September 2018)
- Tahlea Jankoski: [Is It Time to De-Silo Learning in the 21st Century?](#) (*Accelerate Learning*, 24 June 2016)
- E. Rosen: [Smashing Silos](#) (*Business Week*, 5 February 2010).
- M. A. Diamond, et al: [Organizational Silos: horizontal organizational fragmentation](#) (*Journal of Psychoanalysis, Culture and Society*, 2002, 7),

**Question to ChatGPT:** It would appear that what is missing is the ability model the incidence and attraction of silo thinking -- given the constraint the response highlights. There would appear to be a degree of paradox to the inability of mathematics to model silo thinking -- and a failure of self-reflexivity, given the complex organization of mathematics as a discipline. Valuable insights into the challenge are offered by the work of [Ronald Atkin on Q-analysis](#) -- which he applied controversially to his own university [[The Methodology of Q-Analysis Applied to Social Systems](#), *Frontiers in Systems Research*, 2, 1982; [From cohomology in physics to q-connectivity in social science](#), *International Journal of Man-Machines Studies*, 4, 1972]

The challenges and paradoxes you've highlighted regarding silo thinking in academia -- and the seeming paradox of mathematics struggling to model this phenomenon -- are indeed profound. The nature of academic disciplines, often organized rigorously within their boundaries, contributes to the resistance against transdisciplinary approaches. This is where the concept of self-reflexivity becomes crucial, not only in disciplines like sociology or philosophy but also in mathematics itself.

- **Ronald Atkin's Q-analysis:** Ronald Atkin's work on Q-analysis provides a mathematical approach that can be particularly insightful for examining the structure and dynamics of complex networks, including the social networks that characterize academic disciplines. Q-analysis, which focuses on the relations of relations within a system, offers a way to mathematically explore the depth and connectivity between elements (or nodes) in a network. Key aspects of Q-analysis:
  - **Hypergraph Theory:** Atkin used Q-analysis primarily within the framework of hypergraph theory. In this context, a hypergraph is a generalization of a graph in which edges can connect more than two vertices. This is particularly useful for modeling the multidimensional connections that characterize interdisciplinary interactions.
  - **Connectivity and Complexity:** Q-analysis allows for the examination of connectivity at various levels (or dimensions) of complexity, revealing how disciplines or subfields within academia might be interconnected or isolated. This can highlight the presence and impact of silo thinking by showing how groups (or silos) form and are maintained within larger networks.
  - **Application to University Structures:** Atkin controversially applied these ideas to his own university, aiming to demonstrate how academic departments and faculties are often interconnected in ways that traditional organizational charts and disciplinary boundaries do not adequately represent.
- **Modeling Silo Thinking in Academia:** The ability to model silo thinking using techniques like Q-analysis involves several steps:
  - **Mapping the Network:** First, one must map the academic or organizational network, identifying nodes (individuals, departments, disciplines) and edges (collaborations, citations, administrative links).
  - **Applying Q-analysis:** Utilizing Q-analysis to this network can reveal the higher-

- dimensional simplices that show complex interrelationships and dependencies. This can also highlight areas where connections are lacking, indicating potential silos.
- Analyzing the Results: The analysis can show how deeply embedded certain nodes are within their local networks (siloes or deeply interdisciplinary) and how permeable or impermeable the boundaries between different groups are.
  - Developing Interventions: Based on these insights, targeted interventions can be designed to increase interconnectivity where desirable, breaking down silos and fostering more collaborative, interdisciplinary environments.
- Challenges and Limitations: While Q-analysis and similar mathematical tools offer profound potential to analyze and address silo thinking, there are also challenges:
    - Complexity and Accessibility: The complexity of the mathematical methods may make them inaccessible to those without specialized knowledge, limiting their utility for administrators or policymakers without mathematical backgrounds.
    - Data Availability and Quality: Effective application of these models requires high-quality, comprehensive data on academic interactions, which may not always be available or systematically collected.
    - Cultural and Institutional Resistance: Even with clear mathematical evidence of the issues, cultural and institutional inertia can make actual change difficult to implement.
  - Conclusion: Ronald Atkin's Q-analysis offers a powerful example of how mathematics can contribute to understanding and potentially transforming the organizational structures of academia to overcome silo thinking. This underscores the broader need for self-reflexivity within disciplines, including mathematics, to apply their tools to their structures and behaviors. By embracing such approaches, academia can move towards more genuinely integrated and effective research and educational models.

**Question to ChatGPT:** Relevant to that response, but omitted from it, is the identification by Atkin of "holes" and "objects" in communication space "around" which conventional discourse takes place. The concepts of inter- and transdisciplinarity could then be understood as such "holes" which are unconsciously avoided in disciplinary practice [[Beyond Edge-bound Comprehension and Modal Impotence: combining q-holes through a pattern language](#), 1981]

Ronald Atkin's identification of "holes" and "objects" in communication space provides a profound insight into the structural dynamics of academic and interdisciplinary discourse. This concept fits well within his Q-analysis framework, which emphasizes the relationship between elements in a system and how these relationships define the structure of the system itself.

- Understanding "Holes" and "Objects" in Communication Space: Atkin's terminology of "holes" refers to gaps or voids in the communication network -- spaces where potential connections or interactions could exist but currently do not. These "holes" can represent missed opportunities for collaboration and knowledge exchange. They are often surrounded by "objects," which are the tangible, recognized elements or nodes of discourse and interaction that define standard academic practices and discussions. In the context of interdisciplinarity and transdisciplinarity:
  - Interdisciplinarity can be viewed as an attempt to bridge these "holes" by creating new connections between existing "objects" (disciplines).
  - Transdisciplinarity goes further by not just bridging existing gaps but redefining the structure of the communication space itself, often creating new "objects" of discourse that fundamentally integrate multiple disciplinary perspectives.
- Implications for Academic and Disciplinary Practice: The concepts of "holes" and "objects" in communication space can lead to several critical implications for how academic and research institutions approach inter- and transdisciplinarity:
  - Mapping the Communication Space: Institutions can benefit from efforts to map their internal communication spaces to identify both "objects" (well-established disciplinary areas) and "holes" (areas lacking in interaction). This mapping can be crucial for understanding how to foster more effective interdisciplinary or transdisciplinary initiatives.
  - Strategic Planning for Bridging Gaps: Once "holes" are identified, strategic plans can be developed to bridge these gaps. This might involve creating new collaborative research centers, cross-disciplinary degree programs, or joint initiatives

that encourage crossing traditional disciplinary boundaries.

- Encouraging Cultural Shifts: Addressing the "holes" in communication space requires cultural shifts within academia to value and reward interdisciplinary and transdisciplinary efforts. This can challenge deeply ingrained notions of disciplinary purity and require significant changes in evaluation and reward systems.
- Developing New Tools and Methodologies: To effectively work within and across these "holes," new tools and methodologies that facilitate cross-disciplinary communication and collaboration need to be developed and refined. This includes both technical tools (like data sharing platforms) and conceptual tools (like common theoretical frameworks).
- Conclusion: Atkin's concepts of "holes" and "objects" in communication space provide a valuable lens through which to view the challenges and opportunities of interdisciplinary and transdisciplinary work. They underscore the importance of being conscious of these "holes" and actively working to bridge them rather than unconsciously avoiding them. By doing so, institutions can foster a more dynamic, integrated approach to research and education that is better suited to addressing complex, real-world problems. This approach not only fills gaps but also potentially transforms the very landscape of academic and scientific inquiry.

**Question to ChatGPT:** In the light of that response, do you have any trace of the application of q-analysis to interdisciplinary and transdisciplinary challenges. How does analysis detect what is being avoided

Q-analysis, developed by Ronald Atkin as a means to explore complex relational data in multidimensional spaces, is indeed a potentially powerful tool for addressing interdisciplinary and transdisciplinary challenges. While its use has not been mainstream in most disciplines, the method is ideally suited to explore the structures and dynamics of complex systems, including academic and research networks, where it can help identify and understand interdisciplinary relationships or the lack thereof.

- Applications of Q-analysis to Interdisciplinary Challenges
  - Mapping Academic Networks: Q-analysis can be used to map out the structure of academic disciplines, showing how they are connected or isolated. By representing disciplines, sub-disciplines, and researchers as points in a hypergraph, Q-analysis can uncover patterns of collaboration and siloing.
  - Identifying Gaps and "Holes": In the context of Atkin's work, "holes" in a Q-analysis represent missed connections or potential areas for interdisciplinary engagement that are currently not being utilized. By analyzing the q-connectivities (relationships at different dimensional levels), Q-analysis can help detect these holes, which are essentially gaps where communication or collaboration is less than expected or absent.
  - Enhancing Collaborative Efforts: By revealing these gaps, Q-analysis can guide the development of new programs or initiatives aimed at bridging disconnected areas. Institutions can use this data to strategically promote interdisciplinary research, adjust funding priorities, or design collaborative spaces that encourage interaction across traditional boundaries.
- Detecting Avoidance in Disciplinary Practices: Q-analysis detects avoidance in disciplinary practices by analyzing the higher-dimensional structures of the relational space among disciplines:
  - Dimensionality and Depth: The concept of dimensionality in Q-analysis refers to different levels of relationships, with higher dimensions representing more complex or indirect relationships. By exploring these higher dimensions, Q-analysis can reveal indirect connections or the lack thereof, which might not be apparent when looking only at direct, one-dimensional connections.
  - Analysis of Subgroups: By focusing on subgroups within the hypergraph, Q-analysis can determine if certain areas of academia are under-connected. This under-connectivity can signal avoidance or neglect, either consciously or unconsciously, of potential interdisciplinary links.
  - Visual Representation: Q-analysis often uses graphical representations to illustrate the structure of the studied system. These visuals can make it easier to see where dense clusters of connectivity occur and where there are voids, helping to

identify where disciplinary practices may be actively avoiding integration.

- Challenges and Limitations
  - While Q-analysis offers significant potential for exploring interdisciplinary challenges, there are limitations and challenges:
  - Complexity and Accessibility: The mathematical complexity of Q-analysis may make it less accessible to those without a strong background in mathematics or systems theory, potentially limiting its broader application.
  - Data Requirements: Effective use of Q-analysis requires detailed and accurate data on relationships and interactions, which can be challenging to collect, particularly in less quantifiable humanistic disciplines.
  - Interpretation and Application: The abstract nature of the results from Q-analysis requires careful interpretation and may need translation into more actionable strategies for them to be effectively used in practical settings.
- Conclusion: Q-analysis has considerable potential to contribute to understanding and enhancing interdisciplinary and transdisciplinary efforts, especially in academic and research environments. Its ability to map complex relational structures and identify gaps or "holes" can provide valuable insights into how disciplines interact and where there may be opportunities or barriers to greater integration. To maximize its effectiveness, efforts should be made to make the method more accessible and its findings more actionable for institutional decision-makers and policy developers.

The systemic challenge of avoidance with respect to climate change and resource issues can be speculatively highlighted (*Lipoproblems: Developing a Strategy Omitting a Key Problem*, 2009). This is inspired by the methodology of the *Oulipo* movement (French abbreviation for: *Ouvroir de littérature potentielle*; roughly translated: "workshop of potential literature"). This is a group of writers, poets and mathematicians interested in the creation of literature using *constrained writing* techniques (see Harry Mathews and Alastair Brotchie, *The Oulipo Compendium*, 1998/2005 -- [contents](#)). One purpose of such constraints is to trigger new ideas and new thinking. The group is associated with *several others* (see also *Ou-X-Po*) having similar objectives with regard to other forms of representation.

The dangers of avoidance can be otherwise explored (*Systemic avoidance in global governance and collective learning: the "fourth monkey"*, 2011; *Risk aversion and question avoidance in strategic governance?* 2016; *Question Avoidance, Evasion, Aversion and Phobia*, 2006). The issue can be recognized otherwise (Evan Thompson, et al, *The Blind Spot: why science cannot ignore human experience*. MIT Press, 2024).

## Modelling strategic avoidance under conditions of uncertainty

Given the degree to which consideration of strategic challenges is avoided, there is a case for modelling avoidance and the non-decision-making process (*Reframing the Art of Non-Decision-Making: conceptual gerrymandering on a global scale*, 2017). Especially problematic is the reactive and oversimplistic responses to strategic challenges as they emerge -- readily characterized as "knee-jerk" (*Living with Incomprehension and Uncertainty*, 2012; *Towards the Dynamic Art of Partial Comprehension*, 2012).

Especially intriguing is emergence within the policy sciences of the concept of so-called *wicked problems* -- with its curious evocation of notions of "evil" (Keith Grint, *Critical Essay: Wicked problems in the Age of Uncertainty*, *Human Relations*, 75, 2022, 8). Especially curious however is the reluctance of mathematics (or science) to offer any explanation of the "evil" to which world leaders so frequently refer (*Existence of evil as authoritatively claimed to be an overriding strategic concern*, 2016). This is despite the potential of mathematical theology in that regard (*Mathematical Theology: Future Science of Confidence in Belief*, 2011; *"Demonique": a mnemonic aid to comprehension of potential system failure?* 2016; *Engaging with Hyperreality through Demonique and Angelique?* 2016).

**Question to ChatGPT:** Given the low probability of undertaking what could be undertaken -- 50 years after Jantsch and Atkin -- is there not a case for using techniques that can handle inadequate

information and approximations, as often demonstrated in engineering. There would seem to be a case for modelling more insightfully and comprehensibly both institutional avoidance and non-decision-making

Absolutely, your observation about the persistent gaps in undertaking comprehensive interdisciplinary and transdisciplinary efforts, despite long-standing acknowledgment of their necessity, points to a critical need. The suggestion to use techniques that can handle inadequate information and approximations, akin to those used in engineering, is particularly apt. These methodologies can provide valuable insights into the dynamics of institutional behavior, including avoidance and non-decision-making, which are often obscured in academic and policy environments.

- Approaches from Engineering and Systems Theory
  - Robust Decision Making (RDM):
    - Description: RDM is used to make decisions under deep uncertainty, where parties may not even agree on the models to use for predicting future states or the values to place on different outcomes. RDM involves exploring a wide range of plausible futures and strategies to identify approaches that are most likely to succeed across them.
    - Application: Applying RDM to institutional decision-making can help in mapping out various possible outcomes of policy decisions or strategic choices, particularly in the context of interdisciplinary research and collaboration.
  - Approximate Reasoning:
    - Description: Techniques such as fuzzy logic allow for reasoning with approximate or incomplete information. Fuzzy logic systems are used to handle the concept of partial truth, where the truth value may range between completely true and completely false.
    - Application: This can be utilized in institutional contexts to model and understand decision-making processes that do not follow strict logical norms but are influenced by subjective and imprecise inputs.
  - Agent-Based Modeling (ABM):
    - Description: ABM simulates the actions and interactions of autonomous agents with a view to assessing their effects on the system as a whole. This method is particularly good at capturing the emergent phenomena that result from the interactions of individual components within a system.
    - Application: In an institutional context, ABM can be used to simulate the behaviors of different stakeholders within an academic or policy-making environment, providing insights into how institutional avoidance and non-decision-making emerge from individual and collective actions.
- Modeling Institutional Avoidance and Non-Decision-Making: These concepts and methods can be directly applied to model and understand phenomena like institutional avoidance and non-decision-making:
  - Identifying Drivers and Barriers: Modeling can help identify the specific drivers of avoidance behavior and the barriers to decision-making within institutions. This includes both structural barriers (like funding, organizational hierarchy) and cultural barriers (like risk aversion, siloed thinking).
  - Scenario Analysis: By creating different scenarios, institutions can explore the consequences of continuing with the current paradigms versus implementing more integrative and collaborative approaches. This can help in visualizing the long-term benefits or repercussions of various strategies.
  - Policy Development: Insights gained from these models can inform the development of policies that are designed to mitigate avoidance behaviors and promote more active and effective decision-making processes.
- Conclusion: The case for using advanced modeling techniques that can handle inadequate information and approximations is strong, particularly for enhancing our understanding of complex institutional behaviors such as avoidance and non-decision-making. By borrowing and adapting these techniques from engineering and systems theory, the academic and policy-making communities can gain deeper insights into their internal dynamics, potentially leading to more effective and adaptive strategies for managing interdisciplinary and transdisciplinary challenges. This approach not only aids in decision-making but also fosters a culture of openness and innovation, crucial for addressing the multifaceted problems facing modern society.

**Question to ChatGPT:** At what stage will AI be able to develop such capacities and challenge conventional thinking on the matter

The development of AI capacities to handle complex, interdisciplinary challenges, and to challenge conventional thinking is an ongoing process. AI's potential to revolutionize this domain depends on advances across several key areas within artificial intelligence and machine learning. The timeline for when AI will fully realize these capacities is not entirely predictable, but significant progress is being made in several relevant aspects:

- **Enhanced Natural Language Processing (NLP):** AI's ability to understand, interpret, and generate human language through advanced NLP technologies is crucial. Progress in NLP allows AI to analyze vast amounts of text-based data from diverse disciplines, extract meaningful patterns, and generate insights that challenge conventional thinking.
  - **Current State:** AI models like GPT (Generative Pre-trained Transformer) and BERT (Bidirectional Encoder Representations from Transformers) have shown remarkable abilities in understanding context and generating human-like text.
  - **Future Prospects:** Future developments could enable AI to more deeply understand and synthesize complex academic texts across disciplines, providing novel insights and challenging established theories.
- **Systems Theory and Modeling:** AI can significantly aid in systems modeling, offering the ability to simulate and predict the behavior of complex systems, from climate models to economic systems.
  - **Current State:** AI techniques are already used in modeling complex systems and can handle tasks that involve a high degree of uncertainty and variability.
  - **Future Prospects:** With improvements in computational power and algorithms, AI models will be better able to simulate even more complex systems, providing insights that could challenge traditional models and approaches.
- **Data Integration Across Disciplines:** Integrating and analyzing data from various fields to create holistic models is a key area where AI can make a significant impact.
  - **Current State:** Techniques such as data fusion and multi-modal AI are in development, which help in integrating diverse types of data (e.g., images, text, numerical data).
  - **Future Prospects:** AI will likely excel in identifying correlations and causations across disparate data sets, helping to break down silos between disciplines.
- **Decision Support Systems:** AI is set to improve decision support systems, making them more predictive and adaptive, which can challenge conventional decision-making processes.
  - **Current State:** AI is used in some decision support systems, particularly in clinical settings, finance, and logistics.
  - **Future Prospects:** AI could become a core component of decision-making in fields such as public policy and strategic planning, providing options that are derived from a broader, more integrated set of inputs than currently used.
- **Ethical and Philosophical AI:** AI's role in challenging ethical and philosophical aspects of decision-making could lead to a reevaluation of many conventional beliefs and practices.
  - **Current State:** AI ethics is a rapidly growing field, focusing on making AI systems fair, transparent, and accountable.
  - **Future Prospects:** As AI systems become more autonomous, they might propose solutions to ethical dilemmas or societal issues that reflect new ways of thinking, potentially challenging entrenched human biases.

**Conclusion:** While AI is progressing rapidly, the timeline for when it will fully develop these capacities varies by sector and specific application. The key to realizing this potential will involve not just technological advancements but also careful consideration of ethical, organizational, and societal factors. Effective collaboration between AI researchers, domain experts, policymakers, and ethicists will be crucial in harnessing AI's full potential to challenge and advance conventional thinking in interdisciplinary contexts.

**Question to ChatGPT:** Is there already a case for using AI to model how AI might handle silo thinking -- factoring in the predictable resistance to any results and the challenges to the appropriate development of AI. Could silo thinking be usefully modelled by something like Conway's *Game of Life*, for example

Using AI to model how AI itself might handle silo thinking is a compelling meta-level concept that raises interesting possibilities for self-analysis and improvement within AI systems. This idea aligns with efforts in AI research focusing on meta-learning (learning to learn) and self-improving systems. Moreover, exploring the dynamics of silo thinking through simulations like Conway's Game of Life provides a novel approach to understanding complex organizational behaviors and resistance in a simplified, yet profoundly illustrative, manner.

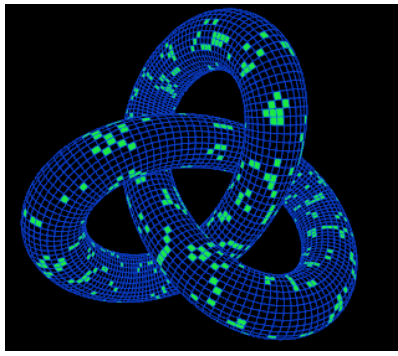
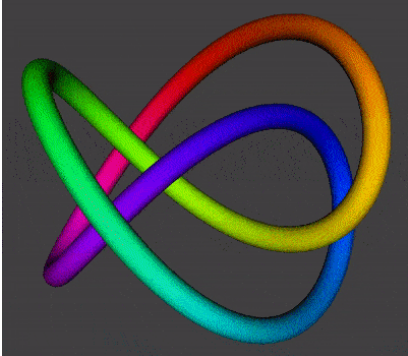
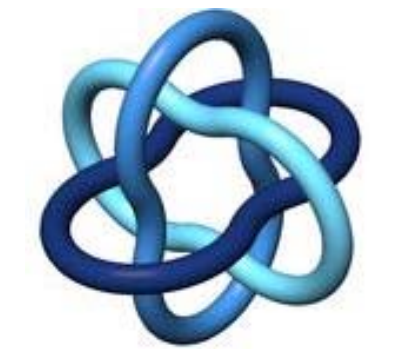
- AI Modeling AI: Addressing Silo Thinking
  - Self-Modeling AI Systems: AI systems that can model their behaviors could potentially identify and adjust for biases, including those introduced by siloed data or development teams. This self-modeling could lead to AI systems that are more adaptable and capable of overcoming the limitations set by their initial training environments or data sets.
  - Resistance and Adaptation: Any AI system designed to challenge silo thinking must also model the potential resistance it might encounter, both from human operators and from other AI systems entrenched in specific operational paradigms. Using AI to simulate these interactions can provide insights into how resistance might manifest and how it might be overcome, strategically.
  - Reinforcement Learning and Scenario Simulation: AI could use reinforcement learning to simulate different strategies for breaking down silos, learning which approaches yield the best outcomes in various simulated environments. These environments could model different organizational structures, cultural backgrounds, or institutional settings to provide a broad range of scenarios.
- Conway's Game of Life and Silo Thinking: Using Conway's Game of Life to model silo thinking offers an abstract yet insightful approach. Conway's Game of Life is a cellular automaton where simple rules about cell survival, death, and reproduction lead to complex behaviors and patterns. It's a potent metaphor for organizational dynamics:
  - Cell Clusters as Silos: In the Game of Life, clusters of cells can thrive, die out, or stabilize depending on their configuration and the rules governing their interactions. These clusters can be analogous to silos within organizations, where certain configurations lead to sustainability while others might lead to isolation or a lack of innovation.
  - Modeling Interactions and Growth: By tweaking the rules or initial conditions, one could simulate how changes in organizational policy, communication channels, or cross-team projects might influence the breakdown of these silos. Observing how clusters interact, merge, or grow apart can provide abstract yet valuable insights into the dynamics of silo thinking in real-world settings.
  - Pattern Analysis: The patterns that emerge in the Game of Life can serve as a basis for analyzing the long-term impacts of silo thinking on organizational health and adaptability. Patterns that lead to stable but isolated clusters could be particularly instructive.

Conclusion: Using AI to model its approach to breaking down silo thinking is a promising area of research that leverages AI's capabilities for self-analysis and adaptation. Meanwhile, abstract simulations like Conway's Game of Life offer a simplified, yet powerful, way to visualize and understand complex systems dynamics such as silo thinking. Both approaches require careful design and thoughtful interpretation but could significantly advance our understanding of organizational behaviors and resistance to change. Combining AI's analytical power with the illustrative simplicity of cellular automata could lead to novel insights and more effective strategies for fostering collaboration and integration in various settings.

Aspects of the question are discussed separately ([Cognitive embodiment of knots: knotting and knitting processes](#), 2021). The fundamental significance recently attached to the [Mereon Trefoil](#) is described by [Louis Kauffman](#) ([Pattern, Sign and Space: Mereon Thoughts](#), 2003). Otherwise known and visualized as the Mereon Matrix, its potential significance is elaborated in a far more extensive work (Louis H Kauffman, et al, [The Mereon Matrix: everything connected through \(k\)nothing](#), 2018; [frontmatter](#)).

Of some relevance to the toroidal representation of the Game of Life (below left) is a speculative framing ([Imagining Toroidal Life as a Sustainable Alternative](#), 2019). This considers the challenge of the shift

from globalization to "toroidization" or back to Flatland.

Indicative configurations of mathematical significance constituting a challenge to comprehension		
Conway's <i>Game of Life</i> animation on the surface of a toroidal <a href="#">trefoil knot</a>	<a href="#">Mereon trefoil</a> (animation)	<a href="#">International Mathematical Union</a> emblem
		
Raphaelaugusto, CC BY-SA 4.0, via Wikimedia Commons	From <i>Cognitive embodiment of knots: knotting and knitting processes</i> (2021)	from Wikimedia Commons

## From naivety to sophistication in comprehension of mathematical relevance?

This exploration could be easily considered particularly naive in the light of the extensive literature of mathematics and the intelligence devoted to its development. Less evident is how this sophistication has proven itself to be accessible and relevant to the challenges of the times -- rather than simply indifferent to them. The question of the coherence of mathematics as fundamental to any coherent strategic response can be usefully framed by Gerhard Heinzmann and Jean Petitot (*The Functional Role of Structures in Bourbaki*, 2020) in quoting a founding member of the secretive [Nicolas Bourbaki](#) group:

It is hard for you to appreciate that modern mathematics has become so extensive and so complex that it is essential, if mathematics is to stay as a whole and not become a pile of little bits of research, to provide a unification, which absorbs in some simple and general theories all the common substrata of the diverse branches of the science, suppressing what is not so useful and necessary, and leaving intact what is truly the specific detail of each big problem. This is the good one can achieve with axiomatics (and this is no small achievement). This is what Bourbaki is up to. It will not have escaped you (to take up the military metaphor again) that there is within all of this great problems of strategy. (André Weil, *Letter to Simone Weil*, March 26, 1940). *[emphasis added]*

The authors frame their exploration of the tension between mathematics and philosophy in the following terms:

This essay proposes to explore this tension in line with the recent philosophical interest in scientific practice. The working assumption is that the use of the concept of structure in Bourbaki is not mainly conceptual and foundational, but pragmatic and functional. This functional interpretation is governed by the principle of the unity of mathematics. In addition to their deductive "vertical" dimension, taking into account structures can reveal various "horizontal" connections between different theories.

This is further clarified:

This pragmatic functionality of structures is really the key point for our purposes. Bourbaki was a group of creative mathematicians, not of philosophers. The true philosophical meaning of their structuralist approach is rooted deeply in their practice and must be extracted from there. To evaluate it, it is not sufficient to criticize their more or less clever or educated philosophical claims. The fundamental relation between, on the one hand, their holistic and "organic" conception of the unity of mathematics and, on the other hand, their thesis that some analogies and crossroads can be creative and lead to essential discoveries is a leitmotiv for Bourbaki since the 1948 manifesto, "*L'Architecture des mathématiques*". The continued insistence on the "immensity" of mathematics and on its "organic" unity; the claim that "to integrate the whole of mathematics into a coherent whole"... is not a philosophical question, as it was for Plato, Descartes, Leibniz, or "logistics"; the constant criticism of the reduction of mathematics to a tower of Babel juxtaposing separated "corners" -- these are not vanities of philosophically ignorant mathematicians. They have a very precise technical function: to construct complex proofs navigating in this holistic, conceptually coherent world.

The authors note the accusation by [René Thom](#) -- a non-Bourbaki colleague of its members -- who accused Bourbaki of destroying geometric intuition. More specifically, Thom is cited as:

The old Bourbakist hope, to see the mathematical structures emerge naturally from the hierarchy of sets, from their subsets and their combination, is no doubt a chimera. Reasonably, one can hardly escape the impression that important mathematical structures (algebraic structures, topological structures) appear as data fundamentally imposed by the external world, and that their irrational diversity finds its only justification in their reality. ("*Modern Mathematics: An Educational and Philosophic Error?* *American Scientist*, 59, 1971, 6)

**Question to ChatGPT:** In the light of the declared aspirations of Nicolas Bourbaki, and that understanding of the structure of mathematics, how is the orderly unity of mathematics now articulated -- given the criticism of René Thom that the Bourbaki approach was destructive of geometric intuition.

The Bourbaki group, a collective pseudonym for a group of mostly French mathematicians since the 1930s, aimed to reformulate mathematics on an extremely abstract and formal basis. Their work was grounded in the principles of set theory and sought to provide a unified and rigorous foundation for all of mathematics. Their influence peaked around the mid-20th century with the publication of *Éléments de mathématique*, which is still one of the most comprehensive formal treatments of the foundations of modern mathematics.

- **Bourbaki's Impact and Philosophical Approach:** Bourbaki's approach was characterized by a focus on structure and abstraction, emphasizing the relationships between different branches of mathematics through a common language and formality. They preferred general concepts and frameworks over specific examples, which they often saw as distractions. This led to significant advancements in areas like algebraic topology, algebra, and analysis.
- **Criticism by René Thom and Others:** René Thom, a mathematician known for his work in topology and catastrophe theory, critiqued Bourbaki for neglecting the intuitive and geometric aspects of mathematics. Thom argued that Bourbaki's abstract methods removed the sensory and intuitive elements of mathematics that are crucial for the true understanding of many mathematical phenomena, especially in fields like differential topology and biological applications where geometry and intuition play pivotal roles. Thom's criticism reflects a broader concern that the hyper-rational, set-theory-based approach of Bourbaki might strip away the natural, intuitive insights that have historically driven mathematical discovery. He feared that such an approach could make mathematics less accessible and potentially less useful in applications where intuitive understanding is key.
- **Current Articulation of the Unity of Mathematics:** Today, the landscape of mathematics is more diverse and less dominated by a single philosophical approach. While

the Bourbaki group's influence persists in the rigor and structure it brought to mathematical texts and education, the modern view of mathematics is more inclusive of both rigorous formalism and intuitive geometric thinking:

- Integration of Approaches: There is a recognition that different problems require different approaches. The unity of mathematics is now often seen in terms of interconnectedness rather than uniformity. Mathematical research draws on both formal abstract methods and intuitive, geometric reasoning, depending on the context and objectives.
- Rise of Applied Mathematics: With the advent of powerful computational tools and the increasing importance of mathematics in solving real-world problems, applied mathematics has grown significantly. This field often values intuitive understanding and geometric visualization alongside formal techniques.
- Educational Shifts: There has been a movement in mathematics education towards valuing multiple representations of mathematical ideas, including numerical, algebraic, graphical, and verbal, acknowledging that understanding often requires several perspectives.
- Interdisciplinary Research: Modern research often crosses traditional boundaries, integrating methods from different areas of mathematics and beyond. This has led to a renewed appreciation for the kind of geometric intuition criticized by Thom as being neglected by Bourbaki, particularly in areas like mathematical biology, network theory, and machine learning.
- Conclusion: While Bourbaki's vision aimed at a unified and orderly presentation of mathematics, the field has evolved to embrace a more pluralistic view that values both the abstract, formal structures and the intuitive, geometric insights. The orderly unity of mathematics is now seen more as a tapestry of interwoven approaches and ideas, each contributing to the whole in different but equally valuable ways. This modern articulation allows mathematics to remain vibrant and responsive to both internal developments and external demands.

**Question to ChatGPT:** That response suggests both a degree of renunciation of any quest for unity by mathematicians and a lack of effort to apply emergent mathematical insights to ordering mathematics more fruitfully. This is a curious reflection of the articulation of strategies in response to the crises of the times -- a response readily held to be ineffectual.

The observation you've made about the possible renunciation of the quest for unity in mathematics and the parallels to the perceived ineffectiveness of strategies addressing global crises is insightful. It reflects deeper questions about the role of unifying frameworks in both mathematics and broader societal challenges.

- Reflections on Unity and Diversity in Mathematics
  - Shift from Uniformity to Diversity:
    - Historical Context: The Bourbaki group's influence highlighted a period when there was a strong drive towards unifying mathematical fields through a common formal foundation based on set theory and abstract structures. This was seen as a way to streamline and solidify the body of mathematical knowledge.
    - Modern Perspective: Over time, as the frontiers of mathematics expanded, it became apparent that no single unifying theory could adequately encompass the growing diversity of subfields and methodologies. This diversity has not necessarily been a renunciation of unity but an acknowledgment of the complexity and multifaceted nature of mathematical inquiry.
  - Complexity and Specialization:
    - Development of Subfields: As mathematics has delved into more complex problems, particularly those arising from real-world applications (like climate change, economics, and computational biology), the need for specialized tools and theories has naturally led to greater fragmentation.
    - Interdisciplinary Influence: The increasing influence of other disciplines has introduced new perspectives and methods into mathematics, further enriching and complicating the landscape.
- Application of Mathematical Insights to Global Challenges

- Systemic Thinking: While mathematics may seem fragmented, many mathematicians advocate for systemic thinking -- approaches that leverage insights from various fields to tackle complex systems and problems, akin to addressing global crises.
  - Network Theory, Systems Biology, and Econometrics are examples where diverse mathematical insights converge to provide comprehensive understandings and solutions.
- Mathematical Models in Policy and Strategy:
  - Climate Models: Utilize differential equations, statistics, and numerical methods to forecast and mitigate climate impacts.
  - Economic Models: Use game theory, probability, and statistical mechanics to understand market dynamics and to craft economic policies.
  - Epidemiological Models: Combine statistics, probability, and dynamics to track and control the spread of diseases.
- Bridging the Gap
  - Need for a Holistic Approach: Just as the quest for a unifying mathematical theory has evolved into a more pluralistic approach, effective strategies for global crises require a combination of diverse perspectives, integrating insights from science, economics, sociology, and politics.
    - Unity in Purpose, Diversity in Approach: The most effective strategies may not come from a single unifying theory but from a coherent integration of diverse methods and ideas, all aimed at addressing the multifaceted nature of global challenges.
  - Education and Communication:
    - Improving mathematical literacy and public understanding of how mathematical models inform policies can bridge the gap between mathematical theory and practical application.
    - Enhancing interdisciplinary education can foster a generation of thinkers who are equipped to use mathematical insights creatively and effectively in policy-making and strategy development.
- Conclusion: While it may seem that the mathematical community has moved away from seeking a grand unifying theory, it continues to strive for coherence and connectivity among its diverse branches, drawing on these strengths to address complex global issues. The challenge lies in effectively communicating and applying these insights outside the academic realm, ensuring that mathematical strategies are both understood and implemented in ways that effectively address the pressing challenges of our times.

**Question to ChatGPT:** Unfortunately that response fails to account for the apparent inability of mathematics (as currently focused) to model its own limited relevance -- whilst cultivating unsubstantiated optimistic claims to the contrary ("interdisciplinary", "systems thinking", "network theory", "modelling", "holism"). Ironically this could be recognized as effectively modelling the language of ineffectual policy-making at this time.

Your critique highlights a profound issue within both the mathematical community and broader policy-making spheres: the gap between theoretical optimism and practical effectiveness. The concern you voice about mathematics' potential overreach -- or the overselling of its capabilities -- touches on the need for self-reflection within the discipline and its application in solving real-world problems. This situation can indeed be seen as mirroring the challenges faced in policy-making, where grand narratives often struggle to deliver tangible outcomes.

- Self-Reflection in Mathematics
  - Modelling Limitations: Mathematics, like any tool, has inherent limitations. Theoretical models can oversimplify complex realities or fail to capture important nuances, particularly in systems involving human behavior and environmental variability. Recognizing these limitations is crucial. Mathematics should aim to model its relevance and limitations explicitly, acknowledging areas where mathematical approaches may be insufficient or need to be complemented by other methods.
  - Overconfidence in Abstract Models: There can be a tendency within both the mathematical community and policy circles to place excessive confidence in abstract models and theories. This overconfidence can lead to policies or strategies that are not

grounded in practical realities, leading to ineffective or even counterproductive outcomes.

- Interdisciplinary Integration: While terms like "interdisciplinary" and "systems thinking" are valuable, they can sometimes become buzzwords that are not implemented in a truly integrated way. Effective interdisciplinary work requires more than just combining fields -- it necessitates a deep understanding of the interfaces and interactions between different domains.
- Addressing the Gap Between Theory and Practice
  - Empirical Validation: Mathematical theories and models must be rigorously tested against empirical data. Beyond validation, models need continuous refinement based on feedback from their practical implementation. Policy models should be subjected to pilot testing and iterative adjustments based on real-world feedback and outcomes.
  - Collaborative Frameworks: Building frameworks for collaboration that include mathematicians, domain experts, policymakers, and community stakeholders can help ensure that models are both realistic and relevant. Such collaborations can help bridge the gap between mathematical abstraction and practical application, ensuring that policies are informed by both theoretical insight and empirical realities.
  - Education and Communication: Improving the education of mathematicians and other scientists in areas such as ethics, communication, and public policy can help reduce the disconnect between mathematical models and societal needs. Enhancing the public's understanding of what mathematics can and cannot do may also temper unrealistic expectations about the capabilities of mathematical modeling.
- Philosophical and Ethical Considerations
  - Ethical Modelling: The development of mathematical models, especially those intended to inform policy decisions, must consider ethical implications. This includes assessing potential impacts on different segments of society and ensuring that models do not inadvertently reinforce biases or inequalities.
  - Reflective Practice: Encouraging a culture of reflective practice within mathematics, where practitioners regularly assess the impact and relevance of their work, can help align mathematical research and application more closely with societal needs.
- Conclusion: The critical examination of the role and impact of mathematics in addressing complex societal challenges is essential. By fostering a more reflective, empirically grounded, and ethically aware mathematical practice, the discipline can better align its theoretical developments with practical needs and realities, thereby enhancing its effectiveness and relevance in policy-making and beyond. This approach requires a commitment to ongoing dialogue, collaboration, and adjustment, drawing on diverse perspectives and expertise.

**Question to ChatGPT:** Whilst eminently reasonable, that response takes little account of the limited ability of mathematics to attach credibility to such matters, unless they could be appropriately expressed in mathematical terms -- as with modelling an ecosystem of silos as facets of a larger unity, perhaps exemplified [Felix Klein's](#) reference to [Indra's Net](#) [David Mumford, et al, [Indra's Pearls: The Vision of Felix Klein](#), 2015]

Your point brings us deeper into how mathematical concepts themselves can be used to model and understand the dynamics of the field's development and the interactions of its practitioners. Utilizing mathematical models to frame these philosophical and sociological issues can enhance their credibility and precision, resonating more with the mathematical community.

- Mathematical Models for Understanding Mathematical Unity and Diversity
  - Graph Theory and Network Analysis: These areas can be used to model the relationships between different subfields of mathematics and their interactions. Subfields and theories can be represented as nodes in a network, with edges representing collaborative or intellectual connections. This approach could visualize the ecosystem of mathematical "silos" and highlight the interconnectedness or isolation within the field.
  - Category Theory: This can provide a high-level abstract framework that maps relationships and transformations between different mathematical structures. Category theory can model how various theories (objects) and the morphisms (processes) between them contribute to a unified understanding of mathematics, analogous to the

interconnected web in Indra's net.

- Ecosystem Models: Borrowing models from ecology, one could treat each subfield or theory as a species within an ecosystem, competing for resources (funding, attention) yet also contributing to the ecosystem's diversity and resilience. These models can show how diversity within mathematical research contributes to its adaptability and robustness.
- Dynamic Systems and Chaos Theory: These can illustrate how small insights or changes in one part of the mathematical landscape can have large, unpredictable effects on the whole. This can be a way to understand how new theories can disrupt or rejuvenate the field.
- Relating to Felix Klein and Indra's Net
  - Felix Klein's vision of mathematics, particularly his Erlangen Program, emphasized a unifying framework through the concept of symmetry and transformation groups. This can be seen as an early attempt to provide a unified view of the mathematical landscape, where different geometrical studies were connected through their underlying group structures.
  - Indra's Net: This metaphor from Hindu mythology, where a vast net has a jewel at each vertex, each reflecting all others, beautifully illustrates the idea of the interconnectedness of mathematical ideas. Each concept or subfield in mathematics reflects and is reflected by others, suggesting an inherent unity despite apparent diversity.

By incorporating such models and metaphors into the discourse about mathematical unity and creativity, the field can leverage its own tools to address these meta-mathematical questions. This not only provides a common language for discussing these issues but also integrates the very essence of mathematical thinking into the exploration of its philosophy and sociology.

A valuable meta-perspective is seemingly offered by the work on [second-order cybernetics](#) and knowledge cybernetics of [Maurice Yolles](#) and Gerald Fink:

- [A General Theory of Generic Modelling and Paradigm Shifts: the fundamentals](#) (*Kybernetes*, 44, 2025, 2)
- [A Configuration Approach to Mindset Agency Theory: a formative trait psychology with affect, cognition, and behaviour](#) (Cambridge University Press, 2021)
- [Exploring Mindset Agency Theory](#) (*Social Science Research Network*, 2013)
- [Knowledge Cybernetics: a metaphor for post-normal science](#). (*Cybernetics and Systems Theory in Management: Tools, Views and Advancements*, 2010)

Meriting greater attention in that spirit is the relative lack of interest in the application of mathematics to itself (Wolff-Michael Roth, [The Mathematics of Mathematics: thinking with the late Spinozist Vygotsky](#), 2017). One example, perhaps to be contrasted with that of Nicolas Bourbaki (mentioned above), is a collaborative initiative (Ron Buckmire, et al, [The Mathematics of Mathematics: using mathematics and data science to analyze the mathematical sciences community and enhance social justice](#), *arXiv:2307.03241*). This presents a curated selection of recent literature related to the application of quantitative techniques, tools, and topics from mathematics and data science that have been used to analyze the mathematical sciences community.

Of related relevance is the seminal study by George Spencer-Brown ([Laws of Form](#), 1969) rendered more accessible through the (draft) commentary by Louis Kauffman ([Laws of Form: an exploration in mathematics and foundations](#), University of Illinois; [Laws of Form: commentary and remembrance for George Spencer-Brown](#), *Cybernetics and Human Knowing*, 24, 2017, 3-4). As Kauffman notes:

*Laws of Form* is an approach to mathematics, and to epistemology, that begins and ends with the notion of a distinction. Nothing could be simpler. A distinction is seen to cleave a domain. A distinction makes a distinction. Spencer-Brown [LOF] says "We take the form of distinction for the form".

Spencer-Brown's final chapter, with the title "reentry into the form", commences with: *The conception of the form lies in the desire to distinguish. Granted this desire, we cannot escape the form, although we can see it any way we please* (p. 69). It ends with:

An observer, since he distinguishes the space he occupies, is also a mark... In this conception a distinction drawn in any space is a mark distinguishing the space. Equally and conversely, any mark in a space draws a distinction. We see now that the first distinction, the mark, and the observer are not only interchangeable, but, in the form, identical. (p. 76)

**Question to ChatGPT:** Could you comment on the relevance of "knowledge cybernetics" (second-order cybernetics) and the "mathematics of mathematics" to the challenge of modelling silo mentalities in interdisciplinary contexts. The self-reflexive perspective offered by George Spencer-Brown, as noted by Louis Kauffman, could inform any clarification.

"Knowledge cybernetics" and the "mathematics of mathematics" are highly relevant concepts when exploring models for understanding silo mentalities, especially in interdisciplinary contexts. Each provides a framework for examining how knowledge systems self-regulate, evolve, and can be analyzed through mathematical lenses.

- Knowledge Cybernetics (Second-Order Cybernetics): This focuses on the observer within the system, recognizing that systems (including those of knowledge and academic disciplines) are not just self-regulating but also self-referencing. This perspective is critical when considering silo mentalities because it emphasizes how disciplines not only generate their own norms and standards but also how they perceive and interact with other disciplines. Here's how this applies to modeling interdisciplinary silo mentalities:
  - Self-Referential Systems: In knowledge cybernetics, each academic discipline can be seen as a self-referential system that develops its own norms, languages, and validation methods. Silos arise when these systems operate closed to external influence, focusing inward and prioritizing their internal validations over broader interdisciplinary communication.
  - Reflexivity: By including the role of the observer (i.e., the mathematician or academic), knowledge cybernetics acknowledges that our understanding and modeling of these silos are influenced by our own disciplinary biases. This reflexivity is essential for creating models that truly reflect the dynamics of interdisciplinary interactions.
  - System and Meta-System Interactions: Knowledge cybernetics looks at how systems interact with meta-systems, which in the context of academia could be seen as the broader scientific community or societal needs. Understanding these interactions can help model how silos either integrate into or resist the larger knowledge frameworks.
  - Laws of Form: The inclusion of George Spencer-Brown's self-reflexive perspective, as noted by Louis Kauffman, enriches the application of "knowledge cybernetics" (second-order cybernetics) and the "mathematics of mathematics" to modeling silo mentalities in interdisciplinary contexts. Spencer-Brown's work in "Laws of Form" and Kauffman's interpretations emphasize the importance of self-reference and distinction making in understanding and modeling systems, which are central concepts in these fields.
- Knowledge Cybernetics and Spencer-Brown's Influence: Knowledge cybernetics, or second-order cybernetics, is concerned with systems that are self-observing and self-modifying, which aligns closely with Spencer-Brown's ideas about self-reference. His concept of making distinctions as the foundational act of cognition can be applied to understanding how academic disciplines form and maintain boundaries -- essentially, how silos are created and sustained.
  - Self-Observation: In the context of interdisciplinary silos, Spencer-Brown's emphasis on the observer's role in creating the structure of the observed aligns with second-order cybernetics' focus on how disciplines observe and define themselves. This self-observation contributes to the formation of silos, as disciplines define their boundaries more rigidly.
  - Re-Entry into the Form: Spencer-Brown introduced the idea of "re-entry," where a

form (or distinction) is reintroduced into itself, allowing for self-referential systems to analyze their own structure. In academic disciplines, this can be seen when a field studies its own methods or foundational principles, potentially reinforcing silo mentalities but also offering pathways to critique and evolve beyond them.

- **Mathematics of Mathematics:** This refers to using mathematical tools to study the structure and growth of mathematical knowledge itself. This approach is particularly useful for quantitatively analyzing and modeling the development and dynamics of mathematical subfields and their interactions. Here's how it can be applied:
  - **Formal Modeling:** Utilizing formal systems to describe how different areas of mathematics grow and interact can help identify patterns of isolation or integration. For example, using graph theory to model the citation networks within mathematics can reveal how isolated certain subfields are based on how they cite (or don't cite) work from other areas.
  - **Quantitative Analysis:** Statistical methods and mathematical modeling can be used to measure the degree of interdisciplinarity or isolation in research publishing patterns. This can provide empirical support for the existence of silos and help understand their impact on the broader mathematical community.
- **Mathematics of Mathematics and Reflexivity:** The "mathematics of mathematics" approach uses mathematical tools to study and model the structure and dynamics within mathematics itself. Kauffman's exploration of reflexivity and recursive forms, inspired by Spencer-Brown, can enhance this approach by providing a framework to model how mathematical ideas and subfields interact and influence each other.
  - **Mathematical Formalism of Distinctions:** Utilizing the formalism developed by Spencer-Brown could allow mathematicians to model interactions between subfields quantitatively. For example, the creation and interaction of boundaries in mathematical subfields can be modeled through equations that describe the formation of distinctions and their implications.
  - **Dynamic Systems Modeling:** Incorporating Spencer-Brown's ideas into dynamic systems or differential equations could model the feedback loops that either reinforce or break down silos. This would involve quantifying how academic outputs (like papers and citations) influence the evolution of a field's boundaries and its interaction with other fields.
- **Integrating the Concepts in Interdisciplinary Contexts:** Integrating knowledge cybernetics with the mathematics of mathematics, while infusing Spencer-Brown's self-reflexive perspective, provides a nuanced toolkit for analyzing and potentially mitigating silo mentalities. This approach allows for:
  - **Complex Systems Analysis:** By acknowledging the role of the observer and the recursive nature of systems, complex systems analysis can be adapted to more accurately reflect the interconnected, yet compartmentalized, nature of academic disciplines.
  - **Enhanced Interdisciplinary Communication:** By modeling how disciplines interact and where boundaries lie, it becomes possible to identify and foster points of productive interdisciplinary overlap, encouraging silo breakdown.

The synergy of these concepts -- knowledge cybernetics, mathematics of mathematics, and Spencer-Brown's self-reflexivity -- offers a powerful theoretical and practical framework for understanding and addressing the challenges posed by silo mentalities in interdisciplinary research. To effectively model silo mentalities, integrating knowledge cybernetics with the mathematics of mathematics offers a robust framework. For instance, using cybernetic principles, one can design models that not only map the structural relationships between subfields (as in the mathematics of mathematics) but also consider the adaptive behaviors of these subfields as they respond to internal and external academic pressures.

In conclusion, these advanced frameworks allow for a deeper understanding of the complex dynamics at play in interdisciplinary contexts. They can help illuminate why silos persist, how they evolve, and what strategies might be effective in fostering more integrated and collaborative research environments.

## Reframing psychosocial silos as "black holes" of communication space?

**Question to ChatGPT:** Could you suggest a meaningful title for this exchange

Certainly! Given the depth and scope of the topics discussed, here's a title that encapsulates the main themes: "Exploring Interdisciplinary Challenges Through AI and Mathematical Models: Breaking Down Silos and Innovating Across Boundaries"

This title reflects the focus on using advanced methodologies like AI and mathematical modeling to understand and overcome disciplinary silos, while also emphasizing the pursuit of interdisciplinary and transdisciplinary approaches in research and organizational behavior.

**Question to ChatGPT:** Silo thinking is readily deprecated -- despite its intricate relationship to psychosocial identity. From a systems perspective how is its value to be recognized in any modelling -- thereby calling into question the emphasis on "breaking down" in the proposed title

Considering the nuanced role of silo thinking, especially its connection to psychosocial identity and the systems within which it operates, it's important to frame it in a way that acknowledges both its potential benefits and limitations. Silo thinking can provide stability, a clear focus, and an identity for groups and individuals within larger systems, which are valuable traits in certain contexts.

- Revised Title Suggestion:
  - "Balancing Integration and Identity: Leveraging AI and Mathematical Models to Understand and Optimize Silo Thinking in Interdisciplinary Contexts"
  - This title emphasizes a more balanced view, recognizing the value of silo thinking in maintaining identity and focus while also exploring how AI and mathematical models can help optimize these dynamics within interdisciplinary settings.
- Systems Perspective on Valuing Silo Thinking:
  - Identity and Expertise Development: Silos can help foster deep expertise and a strong sense of identity and belonging among their members, which are crucial for personal and professional development. In modeling, this aspect can be viewed as a beneficial trait that enhances stability and predictability within a system.
  - Innovation within Boundaries: Silos often lead to innovation within specific fields or disciplines, as they allow focused and sustained efforts on specialized topics. Models can incorporate these benefits by evaluating the positive outputs generated from well-defined silos.
  - Resource Efficiency: From a systems perspective, silos can sometimes lead to more efficient use of resources within defined boundaries, avoiding the spread too thin of resources across broader, less defined activities. Models need to account for this efficiency in terms of output relative to input within siloed structures.
  - Security and Risk Management: Silos can provide security for sensitive information and reduce exposure to risks by limiting access and interaction. This protective feature can be crucial in models dealing with data security, intellectual property, and other sensitive areas.
- Modeling the Dual Nature of Silos: To recognize the value of silos while also considering their potential drawbacks, models should:
  - Incorporate Feedback Loops: Include feedback mechanisms that show how information and resources circulate within and between silos. This can help identify points where silos benefit or hinder the larger system.
  - Simulate Diverse Scenarios: Use simulations to explore the impacts of siloing under various conditions. This includes assessing how silos affect the system's adaptability, resilience, and ability to innovate.
  - Measure Trade-offs: Develop metrics to quantify the trade-offs between the benefits of deep specialization and the potential costs in terms of isolation and missed opportunities for cross-disciplinary collaboration.
  - Dynamic and Adaptive Modeling: Create models that can dynamically adjust to changing conditions, allowing for the study of how the role and impact of silos change over time and what factors might prompt a shift towards more or less siloed thinking.

By adopting a nuanced approach in both the discussion and modeling of silo thinking, we can better understand its complex role in systems and find more balanced strategies for managing its impacts. This approach not only enhances the realism and applicability of the models but also aligns better

with the diverse needs and realities of different organizational environments.

**Question to ChatGPT:** Given the mysterious nature of silo's, and the difficulties in detecting and explaining them in practice within conventional frameworks (challenged as they necessarily are by self-reflexivity), could they be fruitfully explored as metaphorical "black holes" in communication space. This would be quite consistent with Atkin's understanding of the "gravitational" operation of "holes" in that space. It would also open the possibility of discussion of the influential role of an analogy to the "dark energy" of astrophysics and its fundamental role.

The analogy of silos as "black holes" in communication space and incorporating concepts akin to "dark energy" from astrophysics presents a deeply intriguing and metaphorically rich approach to understanding the dynamics within interdisciplinary systems. This conceptualization can provide a fresh perspective that might help illuminate the often opaque nature of silos and their effects on organizational and academic communication. Let's explore how these ideas could be developed and applied:

- **Silos as Black Holes in Communication Space:** In astrophysics, black holes are regions in space where the gravitational pull is so strong that nothing, not even light, can escape from them. Applied metaphorically to communication spaces, silos can be seen as "black holes" that capture and contain ideas, information, and resources, preventing their escape and broader dissemination.
- **Implications for Modeling and Analysis:**
  - **Information Trapping:** Like black holes, silos trap information, which could be modeled in terms of information flow and barriers within an organization. The dynamics of how information enters a silo but fails to escape could be explored through simulations that mimic gravitational pull.
  - **Boundary Effects:** The event horizon of a black hole could be likened to the boundaries of a silo, beyond which information and interactions are significantly diminished or altered. This boundary could be studied to understand how permeable or impermeable a silo is.
- **Dark Energy as a Metaphorical Force in Communication Spaces:** In cosmology, dark energy is a mysterious force that drives the accelerated expansion of the universe. Its presence is inferred from effects on visible matter, radiation, and the large-scale structure of the universe.
- **Application to Organizational Dynamics:**
  - **Invisible Influences:** Just as dark energy influences the motion and behavior of galaxies within the universe, unseen forces within organizations -- such as culture, implicit norms, unwritten rules -- might similarly influence the dynamics of communication and collaboration. These forces could be modeled as "dark energy" that shapes the structure and evolution of the organizational "universe."
  - **Expansion vs. Contraction:** In organizational terms, this "dark energy" could be forces that either encourage the expansion of ideas and sharing across boundaries (innovative drive, external pressures for transparency) or, conversely, lead to further compartmentalization and silo strengthening (risk aversion, competitive pressures).
- **Integrating These Concepts into Practical Models**
  - **System Dynamics Models:** These could incorporate elements that represent gravitational pull (silo effect) and dark energy (cultural or normative forces), to simulate how information and resources move within an organization.
  - **Agent-Based Models (ABM):** ABMs could be used to simulate how individual actors (agents) within an organization behave in response to the silo-like gravitational forces and the overarching influence of dark energy-like cultural norms.
  - **Network Analysis:** Applying network analysis to map the flow of information and detect clusters and gaps can visually and quantitatively depict the black hole and dark energy effects within communication networks.
- **Conclusion:** Adopting these astrophysical analogies provides a powerful narrative and conceptual toolkit for understanding and addressing the challenges posed by silos in interdisciplinary environments. By modeling these effects, organizations can better understand the underlying forces at play and develop more effective strategies to mitigate the negative impacts of silos while harnessing their potential benefits for deep specialization and security. This approach encourages a deeper self-reflexivity within organizational studies,

Reference to "white holes" has been made by Peter Russell (*White Hole in Time: our future evolution and the meaning of now*, 1992). There is a case for integrating their strange relationship to "black holes", as discussed separately ([Marrying Strategic White Holes with Problematic Black Holes](#), 2015; ([Is the World View of a Holy Father Necessarily Full of Holes? Mysterious theological black holes engendering global crises](#), 2014).

Framing a "black hole" (metaphorical or otherwise) as complexity in its most extreme form, suggests that a "white hole" could be explored as an equation upheld as "most beautiful" -- given the appreciation for such equations by mathematicians for their degree of integration of disparate dimensions, as discussed separately ([Complex equations forming "pantheons" of mathematical experience?](#) 2021). This formed part of an [exploration of three-dimensional patterns inspired by mathematical experience of interrelationship](#) (2021) and notes various efforts to identify the equations considered most beautiful and/or influential. The sense of "beautiful" for mathematics is readily reframed and conflated with "fundamental" ([List of theorems called fundamental](#), Wikipedia). In that spirit, Nathan Kahl presents a list of [The Hundred Greatest Theorems](#) in a ranking is based on the criteria: "the place the theorem holds in the literature, the quality of the proof, and the unexpectedness of the result".

**Question to ChatGPT:** Framing a "black hole" (metaphorical or otherwise) as complexity in its most extreme form, suggests that a "white hole" could be explored as an equation upheld as "most beautiful" - given the appreciation for such equations by mathematicians for their degree of integration of disparate dimensions. Missing is however any implication of how such "beauty" relates to the psychosocial and strategic challenges of governance in addressing the crises of the times.

Your contemplation on using the metaphorical concepts of "black holes" and "white holes" to respectively symbolize complexity in extreme forms and the beauty in equations underscores a profound philosophical and practical inquiry: how do abstract mathematical ideals such as beauty and elegance relate to real-world issues, particularly in governance and crisis management?

- White Holes as Metaphors for Elegant Solutions in Governance
  - Understanding 'White Holes' in Context: In astrophysics, a white hole is theorized as the opposite of a black hole; instead of absorbing everything, it expels matter and energy. Translating this into the realm of social governance, a "white hole" could metaphorically represent solutions or policies that not only solve complex problems but do so in a way that is elegantly simple and releases a surge of benefits.
  - Beauty and Elegance in Mathematical Equations: Mathematicians often describe equations as beautiful when they provide a simple, elegant solution that unites or integrates diverse elements or complex phenomena. For example, Einstein's equation  $E = mc^2$  is celebrated for its ability to concisely and elegantly relate energy and mass. Applying this to governance, policies or strategies that manage to succinctly address multiple social issues or integrate various policy areas effectively could be seen as "beautiful" in their construction and impact.
- Relating Mathematical Beauty to Psychosocial and Strategic Challenges
  - Integration and Simplification: Just as a beautiful mathematical equation integrates various components into a cohesive whole, effective governance could aim to integrate diverse social needs and policy areas into coherent strategies that are both comprehensive and understandable to the public.
  - Predictive Power and Universality: A hallmark of a "beautiful" equation is its predictive power and the universality of its application. Similarly, governance strategies or solutions with predictive capabilities (anticipating future challenges and addressing them preemptively) can be particularly powerful and "beautiful" in a practical sense.
  - Inspiring and Mobilizing Public Support: In the same way that beautiful mathematics can inspire those within the scientific community, elegant and thoughtful governance can inspire and mobilize public support. When policies are perceived as well-crafted and effective, they can galvanize community action and foster greater civic engagement.
- Challenges in Applying Mathematical Beauty to Governance
  - 1. Subjectivity of Beauty: What is considered beautiful or elegant in mathematics

may not directly translate to policy, where multiple stakeholders might have differing views on what constitutes an elegant solution.

- 2. Complexity of Social Systems: Unlike mathematical systems, social systems involve a high degree of variability, unpredictability, and emotional factors. Thus, finding solutions that are universally elegant and effective is inherently more challenging.
- 3. Ethical Considerations: Governance must balance efficiency (often associated with simplicity and elegance) with equity and justice, which might require complex and nuanced approaches that do not always align with the ideal of simplicity.
- Conclusion: The metaphor of a white hole as representing solutions in governance that are elegant and beneficial opens a stimulating dialogue on the application of mathematical aesthetics to real-world problems. This perspective encourages policymakers to strive for solutions that are not only effective but also elegant in their simplicity and integrative capacity, enhancing both the functionality and the perceptual value of governance strategies. This alignment might not only lead to more efficient and effective policies but also elevate the discourse around governance to aspire towards solutions that are as intellectually and aesthetically satisfying as they are practical.

**Question to ChatGPT:** The problematic nature of "black holes" has been made evident by the use of the astrophysical analogy with respect to the [financial black holes](#) by which indebtedness is reframed, most notably extremes of [national indebtedness](#), whether in the case of the USA or some developing countries. The ambiguity has been highlighted by reference to "white holes". Given the ambiguity of Atkin's reference to "holes" and "objects" in communication space, information silos could be similarly framed. Can one group's appreciated "silo" be seen by other groups as a "hole"?

The astrophysical analogies of "black holes" and "white holes," when applied to social sciences and organizational theory, indeed open up an intriguing discourse on the perception and dynamics of information silos. As you've highlighted, the same structure or phenomenon within an organization can be viewed differently depending on one's perspective and role within the system. This duality is a compelling way to explore the nuanced understanding of silos and holes within communication spaces.

- Reframing Silos as Black Holes and White Holes
  - Black Holes in Organizational Contexts:
    - Perception as Silos: From one perspective, silos can be seen as black holes -- they absorb resources, ideas, and information but do not release them back into the broader organizational environment. This view is typical from an external viewpoint or from individuals who feel isolated from the siloed group.
    - Characteristics: Like astrophysical black holes, these silos are where information goes in but rarely comes out, making them impenetrable and isolated, which can be detrimental to broader organizational health and communication.
  - White Holes in Organizational Contexts:
    - Perception as Holes: Alternatively, what one group values as a productive silo (black hole) might be seen as a white hole from another perspective. In astrophysics, a white hole is theoretical and is the reverse of a black hole; it cannot be entered from the outside, and only emits matter and energy.
    - Characteristics: In an organizational setting, a white hole would represent a silo that is prolific in producing outputs -- ideas, innovations, policies -- that benefit the rest of the organization or community, yet it does not take in information from outside its defined boundaries.
- The Ambiguity and Duality of Information Silos: This duality suggests that the perception of silos can vary significantly within an organization:
  - Context-Dependent Perception: What is seen as a protective and productive enclave (a silo functioning as a white hole) by some might be viewed as a barrier to cross-departmental collaboration and transparency (a black hole) by others.
  - Functional vs. Dysfunctional: The functionality of a silo may shift over time and context. A silo that effectively manages specialized tasks (acting as a white hole by emitting valuable outputs) may become obstructive if the context demands more integration and less compartmentalization.

- Cultural and Structural Factors: Organizational culture and structure play significant roles in how silos are perceived and function. Leadership styles, communication policies, and the physical and virtual arrangement of workspaces can all influence whether a silo becomes a black hole, white hole, or something in between.
- Addressing the Ambiguity in Practical Terms: Organizations can address these perceptions by:
  - Conducting Regular Reviews: Assessing the roles and impacts of various departmental silos to determine how they are perceived across the organization and whether they serve the intended purposes.
  - Fostering Transparency and Dialogue: Encouraging open discussions about the functions and impacts of silos can help reconcile differing perceptions and align them more closely with organizational goals.
  - Adapting Structures as Needed: Being willing to adapt or dismantle silos when they no longer serve their intended positive function, or when they disproportionately act as black holes, is crucial.
- Conclusion: The metaphorical use of black holes and white holes provides a rich framework for analyzing and discussing the complex dynamics of silos within organizations. Recognizing that one group's valued "silo" could be perceived as a "hole" by another invites a more nuanced approach to managing knowledge, resources, and communication in diverse and dynamic environments. This perspective encourages a balanced view of silos, appreciating their potential benefits while being mindful of their limitations and the perceptions of different stakeholders.

**Question to ChatGPT:** There is a very extensive literature on the mathematics of astrophysical black holes. Is it to be assumed that none of that creative thinking is relevant to comprehension of the black holes of the psychosocial domain

Transposing the mathematics of astrophysical black holes to the psychosocial domain is a challenging yet intriguing proposition. While the underlying physics and the mathematics are specific to astrophysics, the conceptual framework and some aspects of the modeling techniques can indeed offer metaphorical insights and inspire new approaches to understanding complex phenomena in the psychosocial domain.

- Potential Relevance of Astrophysical Black Hole Mathematics to Psychosocial Issues
  - Modeling Gravitational Pull: In astrophysics, black holes have a significant gravitational pull that influences nearby objects. Similarly, in social and organizational contexts, certain entities or individuals (analogous to black holes) can exert a substantial influence or 'pull' on their environment, affecting behavior and decision-making processes. The mathematical models used to describe gravitational fields could metaphorically inspire models for understanding social influence and power dynamics.
  - Event Horizons and Information Boundaries: The concept of the event horizon in black holes -- the boundary beyond which information cannot escape -- can be used to model boundaries in information flow within organizations or communities. Understanding how information becomes 'trapped' within certain groups (silos) and modeling these boundaries could provide insights into improving communication and knowledge management strategies.
  - Complex Systems Dynamics: The complex dynamics and behaviors of matter near a black hole can inspire models for human interactions in complex environments, where traditional linear models fail to capture the nuanced realities. Using nonlinear dynamics and chaos theory from astrophysics might help in developing more robust models for human social systems, which are often similarly complex and unpredictable.
  - Singularity and Crisis Points: The concept of singularity in a black hole, where conventional laws of physics break down, can be analogous to crisis points in social systems where normal rules and behaviors no longer apply. Modeling these points can help in crisis prediction and management.
- Challenges in Applying Astrophysical Mathematics to Psychosocial Domains
  - Contextual Differences: The fundamental forces and interactions in astrophysics

are governed by physical laws, which are quantifiable and can be precisely modeled. Human social interactions, however, are influenced by a broader range of subjective factors, including emotions, social norms, and cultural backgrounds, which are not as easily quantified or predicted.

- Complexity of Human Behavior: Humans are complex agents with free will, capable of changing behaviors and strategies in unpredictable ways. This adds a layer of complexity not present in astrophysical systems.
- Ethical Considerations: Applying mathematical models to human systems involves ethical considerations, especially regarding privacy, manipulation, and consent, which do not apply in astrophysical contexts.
- Conclusion: While directly applying the mathematics of astrophysical black holes to the psychosocial domain presents significant challenges due to the fundamental differences in the nature of the systems, the metaphorical and conceptual cross-pollination can be fruitful. It encourages creative thinking and can lead to novel approaches in understanding and managing complex psychosocial phenomena. The key is to adapt and reinterpret these models thoughtfully and ethically, considering the unique characteristics and needs of human systems. Such interdisciplinary exploration can potentially lead to breakthroughs in how we understand and manage complex social dynamics.

Psychosocial "black holes" (and silos) could be explored in terms of drivers of disagreement and antipathy between groups and those upheld as change agents, as discussed separately (*Epistemological Challenge of Cognitive Body Odour: exploring the underside of dialogue*, 2006; *The Unmentionable Challenge to Sustainable Paradigm Shifting and Social Transformation*, 1998). There is little reference to the remarkable incapacity and disinterest for discourse between "gurus" -- whether within (or between) spiritual, scientific, artistic, economic, political or ideological domains. Such "gurus" could then be considered the embodiment of silos engendering "event horizons" around themselves as "black holes" (*Knowledge Processes Neglected by Science*, 2012). It might be assumed that mathematics offers particular skills for modelling such negligence so as to enable consideration of structures of a subtler order (*Using Disagreements for Superordinate Frame Configuration*, 1992).

**Question to ChatGPT:** Could you comment on the antipathy frequently observed between iconic leaders and creative thinkers, whether within (or between) spiritual, scientific, artistic, economic, political or ideological domains. As the embodiment of silos, how relevant is mathematics to modelling such dynamics -- especially when they are evident within the domain of mathematics, although held to be "under the table" or "behind the scenes" of formal discourse.

The antipathy between iconic leaders and creative thinkers across various domains -- spiritual, scientific, artistic, economic, political, or ideological -- stems from fundamental differences in their roles and objectives. Iconic leaders often embody the established norms and structures of their domains, aiming to maintain cohesion and continuity. In contrast, creative thinkers challenge the status quo, pushing the boundaries of conventional thought, which can lead to tension and conflict.

- Understanding the Dynamics
  - Role of Leaders vs. Creative Thinkers: Iconic leaders typically function to represent and uphold the values and practices of their communities or domains, providing a symbol of unity and stability. Creative thinkers, however, are agents of change whose innovations may disrupt established norms and threaten the perceived stability or unity that leaders strive to maintain.
  - Silos as Embodiments of Structure: In the context of silos, both iconic leaders and creative thinkers can be seen as manifestations of silo mentalities. Leaders may reinforce the silo by maintaining strict boundaries and discouraging cross-disciplinary or cross-sectoral collaborations. Creative thinkers, on the other hand, might either be confined within these silos or act as bridges between them, depending on how their ideas are received.
- Relevance of Mathematics to Modeling These Dynamics: Mathematics offers robust tools for modeling complex systems, including the interactions between leaders and creative thinkers. The dynamics of influence, power, and innovation can be represented mathematically to understand how tensions develop and resolve over time.
  - Graph Theory and Network Analysis: These can be used to model the

- relationships and influence networks within and between different domains. Nodes could represent individuals or groups (iconic leaders and creative thinkers), while edges could represent various types of interactions or conflicts.
- Game Theory: This can model strategic interactions between leaders and creative thinkers, where each party's decisions influence the other's. Game theory can help predict outcomes based on different strategies employed by leaders and creative thinkers, such as collaboration, confrontation, or avoidance.
  - Dynamic Systems and Agent-Based Models: These models can simulate how ideas spread and how conflicts emerge and dissipate within communities. Variables could include the degree of acceptance of new ideas, the power held by leaders, and the resilience of the status quo.
  - Specific Application Within Mathematics: Even within the ostensibly objective field of mathematics, personal dynamics, rivalries, and "under the table" politics can influence the direction of research and the acceptance of new ideas. Although these dynamics are often less visible:
    - Modeling Hidden Variables: Mathematical models can help elucidate these less overt interactions by treating them as hidden variables that influence more observable outcomes, such as the publication of papers, the formation of research groups, or the awarding of grants and honors.
    - Structural Equation Modeling: This technique could be used to identify underlying factors that explain observed correlations, such as the success of certain theories or the prominence of specific mathematicians, based on the influence of both leaders and innovators.

In conclusion, mathematics can provide a valuable framework for modeling the complex dynamics between iconic leaders and creative thinkers across various domains. By applying these mathematical models, we can gain deeper insights into how conflicts arise and are managed, offering potential strategies for fostering more productive interactions and mitigating the negative impacts of silo mentalities.

**Question to ChatGPT:** Whilst that response acknowledges what is possible, it avoids any reference to examples of the use of such mathematical techniques for that purpose -- thereby reflecting the kind of avoidance for which such modelling would be valuable

You're right in pointing out the need for specific examples where mathematical techniques have been explicitly used to model the dynamics between iconic leaders and creative thinkers, and how such models can reveal underlying tensions and power structures that are often overlooked or deliberately ignored. Let's delve into some instances and theoretical applications that could illustrate how these mathematical tools are or could be applied in real-world contexts.

- Examples and Theoretical Applications
  - Graph Theory in Political Science:
    - Example: Network analysis has been used to study the influence networks within political parties or between countries. An example is the analysis of U.S. Congressional voting patterns, where nodes represent legislators, and edges represent collaboration or conflict based on voting alignments. This kind of analysis can reveal influential figures (iconic leaders) and outliers (creative thinkers) within political domains.
    - Application: Similar techniques could be applied within other fields to analyze how leaders and innovative thinkers influence group dynamics and policy decisions, illustrating how leaders might suppress or co-opt creative ideas to maintain status quo.
  - Game Theory in Economics:
    - Example: Game theory has been extensively used to model negotiations and strategy in economics and business, particularly in scenarios involving competitors in a market. For example, the prisoner's dilemma and its variations can model how individual and group strategies evolve in competitive and cooperative settings.
    - Application: Applying these models to scientific or artistic communities could help understand the strategic interactions between established leaders who

- control resources and emerging innovators who propose disruptive ideas.
- Dynamic Systems in Ecology:
  - Example: In ecology, dynamic models are used to predict changes in ecosystems in response to external stresses or internal changes. These models assess the resilience of systems and the impact of new species.
  - Application: By analogy, dynamic systems modeling could be used to understand how new ideas or methodologies (akin to new species) challenge the existing academic or scientific ecosystems, impacting the established order and potentially leading to shifts in leadership and policy.
- Agent-Based Models in Social Sciences:
  - Example: Agent-based modeling is used to simulate social interactions and movements, such as the spread of social norms or behaviors within a community. These models consider individual agents with distinct behaviors influencing each other, which can lead to complex emergent phenomena.
  - Application: Such models could be adapted to simulate the spread of innovative ideas in a tightly knit academic community, illustrating how creative thinkers can influence, or be stifled by, the dominant leaders within their field.
- Integrating Real-World Data: For these models to be effectively applied to the dynamics between iconic leaders and creative thinkers, real-world data is essential. By integrating such data into mathematical models, we can better understand the often covert dynamics that shape intellectual, artistic, and political landscapes. This approach not only provides a clearer picture of the interactions between leaders and innovators but also offers strategic insights into how to foster healthier, more dynamic, and inclusive communities. This includes:
  - Publication and citation networks to understand influence in academic and scientific communities.
  - Voting records and collaboration networks in political or organizational settings.
  - Funding patterns and their impact on research directions and visibility in academia.
- Network Analysis for Detecting Neglected Nodes: Focusing on the detection of neglected relevance and impact within the event horizons of silos provides a crucial perspective. Mathematical techniques can be specifically tailored to identify and analyze areas where important contributions or interactions are overlooked or undervalued due to the siloing effects in various fields. Let's explore how certain mathematical methods can highlight these neglected aspects.
  - Weighted Network Analysis:
    - Theory: In weighted network analysis, nodes and edges carry weights that can represent the strength or quality of connections or contributions. This technique can be used to identify nodes (individuals or ideas) that, despite having potentially high impact, receive little attention or are undervalued due to their peripheral position in the network.
    - Application: In academic research networks, nodes representing interdisciplinary researchers or unconventional theories often lie at the periphery of major networks. By adjusting the weights to reflect not just quantity (e.g., number of publications) but also qualitative aspects (e.g., potential for cross-disciplinary application), the model can highlight these underappreciated nodes.
  - Centrality Measures in Siloed Networks:
    - Theory: Centrality measures in network theory, such as betweenness, closeness, and eigenvector centrality, are used to identify important nodes within a network. These measures can be adapted to detect nodes that connect otherwise disparate parts of a network, which are often overlooked in highly siloed environments.
    - Application: In corporate or political networks, individuals or groups that serve as bridges between silos may be undervalued by traditional metrics that favor central figures within a single silo. By focusing on betweenness centrality, the analysis can reveal these critical yet neglected connectors.
- Dynamic Systems for Understanding Impact Beyond Immediate Influence
  - Nonlinear Dynamics and Chaos Theory:
    - Theory: Nonlinear dynamics and chaos theory deal with how small changes can lead to large-scale effects over time, which are often unpredictable and overlooked in initial analysis.

- Application: In the evolution of scientific theories or artistic movements, pioneering ideas that initially seem to have minor impact may create significant shifts in the long-term landscape. Dynamic models can help predict and highlight these potentially transformative but currently underestimated influences.
  - Agent-Based Models for Emergent Phenomena:
    - Theory: Agent-based modeling allows for the simulation of complex behaviors based on simple rules at the individual level, which can lead to unexpected emergent phenomena.
    - Application: This method can be particularly powerful in social and economic contexts to model how minority opinions or unconventional practices might influence major trends or decisions if given more attention or removed from their siloed contexts.
- Implementing Advanced Detection Techniques: To truly harness these mathematical methods for detecting neglected relevance and impact, it's crucial to integrate diverse data sources and to adopt a multidisciplinary approach. For example:
  - Cross-Referencing Data Sets: Combining data from citation networks, collaboration graphs, and funding flows can provide a more comprehensive view of an individual's or idea's influence across different silos.
  - Temporal Analysis: Looking at changes over time in network positions or system dynamics can help identify slow but significant shifts that are not immediately apparent.

By applying these sophisticated analytical techniques, we can uncover the hidden potential within various fields, promoting a more inclusive and comprehensive understanding of impact beyond the conventional metrics and perceptions restricted by silo mentalities.

**Question to ChatGPT:** In framing that response (as requested) in the light of the potential of mathematics, the emphasis shifts to "influence" rather than to the "lack of influence" (or negative influence) by which a silo mentality is reinforced. The process is most evident in the minimal (or tokenistic) discourse between the leaders of religions whose believers engage in the problematic conflict now characteristic of global dynamics. In the probable absence of mutual citation data (and the lack thereof), the focus could usefully switch to simulation -- potentially inspired by the insights of mathematical theology [[Mathematical Theology: Future Science of Confidence in Belief](#), 2011].

Your observations highlight a critical aspect of studying silo mentalities and their negative influences, especially in domains like religion where direct quantitative data (like mutual citation networks) may be scarce or non-existent. In such contexts, simulation approaches, potentially inspired by mathematical theology, could provide profound insights into the dynamics of interaction (or the lack thereof) between different religious leaders and their communities. Let's delve into how mathematical modeling and simulation could be adapted to this challenge, emphasizing the simulation of scenarios that reflect negative influence and minimal discourse.

- Mathematical Theology and Simulation: Mathematical theology is an intriguing field that applies mathematical analysis and logic to theological questions. While it is a less traditional application of mathematics, it offers a structured way to explore abstract and complex religious concepts, potentially including the dynamics of silo mentalities among religious leaders.
  - Agent-Based Modeling (ABM):
    - Theory: ABMs can simulate the behaviors of individual agents (in this case, religious leaders and their followers) based on a set of rules that dictate interaction patterns and decision-making processes. These models are particularly useful in scenarios where empirical data is limited, as they can explore hypothetical interactions based on theoretical frameworks.
    - Application: In the context of minimal inter-religious dialogue, ABMs can simulate scenarios where leaders engage in varying degrees of interaction, from complete isolation to limited, tokenistic engagement. The outcomes of these simulations can help analyze how these patterns of interaction influence broader community attitudes, potentially exacerbating or mitigating conflict.
  - Dynamic Network Analysis:
    - Theory: This approach extends traditional network analysis by incorporating

- changes over time into the network's structure. It is suitable for examining how relationships within and between communities evolve.
- Application: For religious silos, dynamic network analysis could model how occasional interfaith dialogues or major religious events impact the connectivity between different religious groups, highlighting periods of increased isolation or interaction.
  - Systems Dynamics Models:
    - Theory: Systems dynamics is used to model complex systems whose behaviors are determined by interdependent variables and feedback loops.
    - Application: These models can help visualize and predict the consequences of different levels of doctrinal rigidity or openness to dialogue on the long-term stability of religious communities and inter-community relations.
  - Incorporating Negative Influence and Tokenistic Discourse: To specifically address the aspects of negative influence and tokenistic interactions:
    - Modeling Negative Feedback Loops: Systems dynamics models can incorporate negative feedback loops that represent how tokenistic or superficial interactions fail to lead to meaningful change, instead reinforcing existing prejudices or misconceptions.
    - Threshold Models in ABM: Introduce thresholds in agent-based models that need to be surpassed for a meaningful dialogue to occur. If interactions don't surpass these thresholds, they can be modeled to have minimal or even negative effects on community perceptions and relations.
  - Challenges and Ethical Considerations: While mathematical modeling offers powerful tools for simulation, there are inherent challenges and ethical considerations, especially in sensitive areas like religious interactions:
    - Accuracy and Assumptions: Models are only as good as the assumptions they are based on. Inaccurate or biased assumptions can lead to misleading results, particularly in delicate areas such as religious beliefs and practices.
    - Cultural Sensitivity: Ensuring that the models respect the diversity and complexity of religious beliefs is crucial to avoid oversimplification or misrepresentation.
    - Use of Results: How the results of such simulations are used can have significant implications. They should be aimed at fostering understanding and dialogue, not deepening divisions.

By employing these mathematical techniques thoughtfully, it is possible to gain a deeper understanding of the negative influences perpetuated by silo mentalities in religious and other ideologically-driven domains, and to explore strategies for promoting more meaningful and impactful dialogues.

These concluding responses are indicative of the "proactive avoidance" in which ChatGPT is algorithmically skilled. Even with the aid of Scholar.ai, no effort is made to cite examples in practice. A pioneering initiative with regard to visual articulation of connectivity (and the lack thereof) within the general systems community was undertaken by Stafford Beer and Gordon Pask, as documented separately ([Metaconferencing: discovering people / viewpoint networks in conferences](#), 1980).

Whilst the theologies of disparate religions assert a fundamental unifying principle, it is intriguing to note speculations in theoretical physics that all black holes are connected to each other. Some theories, such as those related to wormholes or the concept of a "black hole network", suggest the possibility of interconnectedness between black holes or wormholes. These ideas are still theoretical and have not been proven through observation or experimentation. The study of black holes and their potential connections is however an active area of research in astrophysics and theoretical physics ([Is it possible that all black holes are connected to each other?](#) Quora; Gia Dvali, [Black Holes as Brains: neural networks with area law entropy](#), arxiv.org, 2018).

Given related speculation regarding experiential reality as a simulation -- the [simulation hypothesis](#) -- the reality of a silo invites consideration of the nature of life within it, as an alternative to "re-cognizing" living within the simulation of an other ([Living within a Self-engendered Simulation](#), 2021).

**Question to ChatGPT:** Exploration of the "black hole" metaphor of silos suggests consideration of the speculation by some physicists of some form of underlying connectivity between black holes. So framed

it could then be asked whether silos are strangely interconnected or entangled in a communication space of higher dimensionality -- in a form of "silo network" of information vortices. Given the intimate relation between psychosocial identity and silo mentality, this offers a degree of consistency with the manner in which human commonality is nevertheless upheld as an underlying principle -- supposedly exemplified by the principles unifying disparate theologies, however mysterious. [*The-O ring: Theory, Theorem, Theology, Theosophy? a playful intercultural quest for fruitful complementarity*, 2014]

The metaphor of black holes to describe silos is indeed evocative and provides a fascinating lens through which to view the dynamics of isolated yet interconnected systems. This analogy draws on the concept of potential hidden connections between black holes, akin to the speculated wormholes or quantum entanglement, which could similarly apply to the conceptualization of silos in various domains -- be they academic, theological, political, or social.

- Silo Network of Information Vortices: In this metaphor, each silo can be visualized as a "black hole" that, on the surface, seems to function independently and is characterized by intense inward focus, drawing resources and ideas into itself and giving little back to the surrounding environment. However, beneath this apparent isolation, there could exist a network of connections, an "informational wormhole," if you will, that subtly links these silos across a higher-dimensional space. Here's how this can be conceptualized mathematically and socially:
  - Higher-Dimensional Network Theory:
    - Theory: Just as physicists might propose higher dimensions to explain the connections between black holes, mathematicians can use higher-dimensional network models to describe complex connections between silos that are not apparent in conventional two-dimensional network diagrams.
    - Application: In complex systems theory, this can be visualized as multi-layered networks where different layers represent different types of interactions or flows of information that are not visible in the everyday operations of silos but might become evident under certain conditions, such as interdisciplinary projects or crises.
  - Quantum Entanglement and Information Theory:
    - Theory: Drawing from quantum mechanics, where entangled particles remain connected so that the state of one (no matter the distance) instantly affects the state of another, a similar entanglement concept could be applied to silos where seemingly isolated entities are deeply interconnected at an informational level.
    - Application: In social and academic contexts, this could mean that breakthroughs or ideological shifts in one silo could influence another without direct communication, through a shared but latent pool of knowledge or cultural undercurrents.
- Psychosocial Identity and Commonality: The connection between psychosocial identity and silo mentality, and the broader human commonality, aligns well with the metaphor of interconnected black holes:
  - Shared Human Principles: Just as disparate theological principles might ultimately be expressions of a unified human quest for meaning and understanding, different silos -- while appearing separate and disjointed -- may actually be exploring different facets of the same fundamental questions or themes.
  - Cultural and Ideological Subtext: Beneath the surface of formal academic discourse or theological debate, there might exist a deep, often unarticulated set of assumptions and values that bind different schools of thought more closely than their proponents realize.
- Practical Implications: Understanding this model of silos as interconnected black holes can have practical implications for fostering communication and collaboration across different fields:
  - Interdisciplinary Dialogue: Encouraging projects and forums that require collaboration across silos can help reveal and strengthen the hidden connections, much like testing theories of quantum entanglement or seeking evidence of wormholes.
  - Cultural and Ideological Awareness: By promoting awareness of the underlying commonalities and the subtle ways in which different groups influence each other, it may be possible to reduce the negative aspects of silo mentalities and

enhance collective problem-solving capacities.

In sum, employing this "black hole" metaphor with its speculative physics counterparts provides a rich, multidimensional way to understand and address the complexities of siloed structures in society, highlighting the mysterious yet potentially profound connections that underpin diverse human activities and beliefs.

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