Article Title: What Lives? A meta-analysis of diverse opinions on the definition of life

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TITLE

"Informational Emergence"

CONSENSUS

Life is a dynamic, emergent phenomenon characterized by the self-organization of matter into complex, information-processing systems capable of sustaining, adapting, and reproducing themselves over time. It operates far from equilibrium, maintaining stability and managing entropy

through the coupling of informational and physical substrates, while evolving through selection pressures that drive increasing complexity and adaptability.

ANALYSIS

Key Themes List

"These definitions share X major themes:"

1. **Information and Computation**
   - Present in all definitions.
   - Life is consistently described as an information-processing or computational phenomenon. This includes self-replication, information storage, and dynamic computation.
   - Used to explain life's ability to adapt, sustain, and evolve.

2. **Self-Organization and Complexity**
   - Present in 7/9 definitions.
   - Life emerges through self-organization of matter or systems into increasingly complex structures.
   - Highlights life's ability to create order and complexity from simpler components.

3. **Dynamic Stability and Adaptation**
   - Present in 6/9 definitions.
   - Life is characterized by maintaining stability over time while adapting to its environment.
   - This includes far-from-equilibrium dynamics and the ability to navigate change.

4. **Physical Substrate and Embodiment**
   - Present in 6/9 definitions.
   - Life is tied to a physical substrate (e.g., matter, energy, or computational systems) but is paradoxically independent of specific material forms.
   - This duality emphasizes the importance of both physical embodiment and abstract informational patterns.

5. **Evolution and Selection**
   - Present in 5/9 definitions.
   - Life is framed as an evolutionary process driven by selection pressures that favor stability, complexity, and adaptability.
   - Evolution is seen as a mechanism for life's increasing diversity and complexity.

6. **Entropy and Thermodynamics**
   - Present in 4/9 definitions.
   - Life is described as managing entropy, maintaining order in the face of natural decay, and exploiting thermodynamic principles.
   - This theme connects life to fundamental physical laws.

7. **Agency and Cognition**
   - Present in 4/9 definitions.
   - Life is associated with agency, decision-making, and cognition, either explicitly or implicitly.
   - This includes the ability to navigate environments and adapt behaviorally.

8. **Emergence and Novel Physical Laws**
   - Present in 3/9 definitions.
   - Life is described as an emergent phenomenon that may involve new physical laws or principles beyond classical physics and chemistry.
   - This emphasizes the uniqueness of life as a natural phenomenon.

Connection Map

"These themes connect in the following ways:"

1. **Information and Computation ↔ Self-Organization and Complexity**
   - Information processing is seen as the driver of self-organization and increasing complexity in living systems.
   - Computational networks are described as the backbone of life’s emergent complexity.

2. **Dynamic Stability and Adaptation ↔ Evolution and Selection**
   - Stability and adaptability are framed as outcomes of evolutionary selection pressures.
   - Life’s ability to maintain order over time is linked to its evolutionary lineage.

3. **Physical Substrate and Embodiment ↔ Entropy and Thermodynamics**
   - Life’s physical substrate is crucial for managing entropy and maintaining far-from-equilibrium states.
   - The interplay between physical matter and informational patterns is central to life’s thermodynamic properties.

4. **Agency and Cognition ↔ Information and Computation**
   - Cognition and agency are described as emergent properties of life’s computational and informational processes.
   - These capabilities allow life to adapt and navigate its environment.

5. **Emergence and Novel Physical Laws ↔ Entropy and Thermodynamics**
   - The emergence of life is tied to thermodynamic principles but may also involve new, undiscovered physical laws.
   - Life's ability to couple information and chemical networks is seen as a unique emergent property.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**
   - All definitions use interdisciplinary frameworks, combining physics, chemistry, computation, and biology.
   - They emphasize systems thinking, focusing on interactions and emergent properties.
2. **Similar Assumptions**
   - Life is fundamentally tied to information and computation, regardless of its physical form.
   - Evolution and self-organization are universal principles underlying life.
3. **Shared Boundaries**
   - Definitions avoid limiting life to carbon-based or Earth-specific forms, allowing for broader applicability.
   - They emphasize life's abstract properties (e.g., information, computation) over specific material instantiations.
4. **Collective Focus**
   - The focus is on life as a dynamic, emergent process rather than a static entity.
   - Definitions highlight life's adaptability, complexity, and ability to sustain itself over time.

Example Patterns

- **Core Idea Flow:** Information → Self-Organization → Complexity → Adaptation → Evolution.
- **Hierarchy:** Physical substrate supports information processing, which drives self-organization, leading to emergent complexity and cognition.
- **Duality:** Life is both dependent on and independent of its physical substrate, emphasizing its abstract, computational nature.

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TITLE

"Self-Maintaining Agency"

CONSENSUS

Life is a dynamic, self-maintaining system that actively resists entropy through energy utilization and metabolic processes, characterized by autonomous agency and goal-directed behavior. It adapts to environmental changes, processes information to sustain internal order, and ensures continuity through reproduction and evolution, creating novelty and maintaining a boundary that enables interaction with its surroundings.

ANALYSIS

Key Themes List

"These definitions share X major themes:"

1. **Self-Maintenance and Homeostasis**
   - Mentioned in 10 definitions.
   - Central to the concept of life as systems that actively maintain their internal states against external disturbances.
   - Used to describe life's ability to resist entropy, adapt to environmental changes, and sustain itself over time.

2. **Reproduction and Continuity**
   - Mentioned in 8 definitions.
   - Highlights the ability of living systems to reproduce, ensuring the continuation of their patterns or lineage.
   - Often tied to concepts of evolution and natural selection.

3. **Agency and Goal-Directed Behavior**
   - Mentioned in 9 definitions.
   - Life is frequently described as having intrinsic goals, purposes, or intentions, enabling it to act autonomously and adaptively.
   - This agency is often linked to decision-making, flexibility, and interaction with the environment.

4. **Energy Utilization and Metabolism**
   - Mentioned in 6 definitions.
   - Living systems are described as open systems that process energy to sustain themselves, reduce entropy, and drive metabolic processes.
   - Energy exchange is often tied to self-maintenance and reproduction.

5. **Adaptation and Evolution**
   - Mentioned in 7 definitions.
   - Life is characterized by its ability to adapt to changing environments, evolve over generations, and exhibit plasticity in behavior or structure.
   - Evolution by natural selection is often cited as a mechanism for complexity and adaptation.

6. **Novelty and Change**
   - Mentioned in 5 definitions.
   - Life is associated with the creation of novelty, variability, and the ability to self-modify in response to challenges.
   - This theme ties into the dynamic and non-static nature of living systems.

7. **Information Processing**
   - Mentioned in 4 definitions.
   - Life is described as systems capable of gathering, utilizing, and encoding information to

pursue goals or adapt to environments.
- Information hierarchies and decision-making processes are emphasized.

8. **Boundary and Open Systems**
   - Mentioned in 4 definitions.
   - Living systems are often defined as open systems with boundaries that separate them from their environment while allowing interaction.
   - This boundary is crucial for maintaining internal order and interacting with external conditions.

9. **Opposition to Entropy**
   - Mentioned in 3 definitions.
   - Life is framed as systems that strive to oppose the Second Law of Thermodynamics by maintaining order and reducing internal entropy.
   - This is often linked to energy utilization and self-maintenance.

Connection Map

"These themes connect in the following ways:"

1. **Self-Maintenance as a Central Hub**
   - Self-maintenance is the most frequently mentioned theme and connects to nearly all others.
   - It relies on energy utilization (metabolism) and is supported by adaptive behaviors and agency to sustain internal order.

2. **Reproduction and Evolution as Continuity Mechanisms**
   - Reproduction ensures the continuation of self-maintaining systems, while evolution introduces novelty and adaptation over time.
   - Both are linked to information processing, as genetic information is central to these processes.

3. **Agency and Goal-Directed Behavior as Drivers of Adaptation**
   - Agency enables systems to interact with their environment, make decisions, and pursue intrinsic goals.
   - This connects to adaptation, as goal-directed behavior often involves responding to stimuli and environmental changes.

4. **Energy Utilization as the Basis for Opposing Entropy**
   - Energy exchange is fundamental to reducing entropy and maintaining order, linking to self-maintenance and metabolic processes.
   - This also supports the dynamic and changing nature of life.

5. **Information Processing as a Mechanism for Adaptation and Agency**
   - Information processing underpins decision-making, goal-directed behavior, and adaptive responses.
   - It also plays a role in evolution, as genetic information evolves over generations.
6. **Boundaries as a Prerequisite for Self-Maintenance**
   - The concept of boundaries ties into self-maintenance by defining the system and enabling controlled interaction with the environment.
   - This supports energy exchange, information processing, and agency.
7. **Novelty and Change as Outcomes of Evolution and Adaptation**
   - The creation of novelty is linked to evolutionary processes and the system's ability to self-modify.
   - This reinforces the dynamic nature of life and its capacity for innovation.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**
   - Most definitions use a systems-based approach, describing life as networks or processes rather than static entities.
   - They emphasize dynamic interactions, energy exchange, and goal-directed behavior.
2. **Similar Assumptions**
   - Life is assumed to be an open system that interacts with its environment while maintaining internal order.
   - Agency, adaptability, and the ability to process information are seen as intrinsic to living systems.
3. **Shared Boundaries**
   - Definitions often focus on the boundary between living and non-living systems, emphasizing self-maintenance, reproduction, and opposition to entropy as distinguishing features.
   - They also highlight the role of energy and information in maintaining this boundary.
4. **Collective Focus**
   - The definitions collectively focus on life as a process rather than a static state, emphasizing change, adaptation, and the creation of novelty.
   - They also highlight the interplay between internal processes (e.g., metabolism, self-regulation) and external interactions (e.g., adaptation, evolution).

Example Patterns and Insights:

- **Dynamic Systems Perspective:** Many definitions frame life as a dynamic, self-organizing process rather than a fixed entity, emphasizing change, adaptation, and interaction.
- **Integration of Biology and Engineering Concepts:** Several definitions borrow from engineering (e.g., automatic control, information processing) to describe life's robustness and adaptability.
- **Entropy and Thermodynamics:** Life is often described in thermodynamic terms, as systems that resist entropy and maintain order through energy exchange.
- **Agency as a Core Feature:** The ability to act purposefully and adaptively is a recurring theme, suggesting that agency is central to our understanding of life.

CLUSTER 3

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TITLE

"Adaptive Complexity"

CONSENSUS

Life is a dynamic, evolving process characterized by the continuous generation of complexity and hierarchical organization through adaptation and novelty production, driven by interactions with the environment.

ANALYSIS

Key Themes List

"These definitions share 4 major themes:"

1. **Life as a Process**
   - Present in all definitions.
   - Life is consistently described as an ongoing, dynamic process rather than a static entity or state. Terms like "process of development," "evolving system," and "statistical novelty producers" emphasize this.
   - This theme is important because it shifts the focus from identifying specific physical or chemical traits to understanding the mechanisms and dynamics of life over time.
   - Used to highlight life’s capacity for change, adaptation, and evolution.

2. **Complexity and Hierarchical Organization**
   - Present in 3 definitions.
   - Life is described as building complexity, either through hierarchical levels ("higher levels out of lower levels"), self-replication with added complexity, or producing statistically improbable patterns.
   - This theme underscores the idea that life is not just about survival but about creating and maintaining intricate systems.
   - Used to explain how life evolves and organizes itself into increasingly sophisticated forms.

3. **Adaptation and Novelty**
   - Present in 3 definitions.
   - Life is tied to the production of novelty, whether through evolution, replication, or statistical improbability. Terms like "novelty producers" and "non-ergodic evolving system" highlight this.
   - This theme is important because it connects life to its ability to innovate and adapt to changing environments.
   - Used to distinguish life from non-living systems, emphasizing its creative and adaptive nature.

4. **Environmental Interaction**
   - Present in 2 definitions.
   - Life is described as interacting with and absorbing structures from its environment to sustain and replicate itself.
   - This theme is important because it situates life within a broader ecological and physical context, emphasizing its dependence on external resources.
   - Used to explain how life sustains itself and evolves in response to external conditions.

Connection Map

"These themes connect in the following ways:"

1. **Life as a Process ↔ Complexity and Hierarchical Organization**
   - Life’s dynamic nature (process) is directly tied to its ability to build and sustain complex, hierarchical systems.
   - For example, the process of "living" involves creating higher levels of organization from lower ones.

2. **Complexity and Hierarchical Organization ↔ Adaptation and Novelty**
   - The production of complexity is a form of adaptation, where life evolves novel structures and mechanisms to survive and thrive.
   - Novelty production is seen as a result of life’s hierarchical and complex organization.

3. **Adaptation and Novelty ↔ Environmental Interaction**
   - Life’s ability to adapt and produce novelty is often driven by its interaction with the environment, absorbing and transforming external structures.
   - For instance, life replicates and evolves by incorporating environmental resources into its systems.

4. **Life as a Process ↔ Adaptation and Novelty**
   - The processual nature of life inherently involves adaptation and the generation of novelty over time.
   - Evolution and novelty production are framed as ongoing processes that define life.

5. **Environmental Interaction ↔ Life as a Process**
   - Life’s processual nature depends on continuous interaction with the environment, which provides the raw materials for replication and evolution.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**
   - All definitions emphasize life as a dynamic, evolving process rather than a static entity.
   - They avoid reductionist approaches, instead focusing on systems, interactions, and emergent properties.

2. **Similar Assumptions**
   - Life is inherently complex and cannot be fully captured by simple models or standard physicalist frameworks.
   - Evolution and adaptation are central to understanding life.

3. **Shared Boundaries**
   - Life is not confined to specific chemical or molecular structures; it is defined by its processes and patterns.
   - Definitions extend beyond Earth-centric or biochemistry-based views, allowing for broader interpretations of life.

4. **Collective Focus**
   - The focus is on life's capacity to evolve, adapt, and produce novelty, rather than on specific traits like metabolism or reproduction.
   - There is an emphasis on understanding life as a system that interacts with its environment and evolves over time.

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TITLE

"Far-From-Equilibrium Systems"

CONSENSUS

Life is a far-from-equilibrium system that sustains itself through the dissipation of energy, enabling autocatalytic self-organization and metabolic processes. It is characterized by defined boundaries that maintain individuation, allowing interaction with the environment while preserving internal coherence. Life adapts and evolves over time through feedback mechanisms and the storage and transmission of information, ensuring dynamic continuity and the capacity for reproduction.

ANALYSIS

Key Themes List

"These definitions share 6 major themes:"

1. **Non-Equilibrium Systems**
   - Used in 10 definitions.
   - Highlights that life operates far from thermodynamic equilibrium, maintaining organization against entropy.
   - Used to explain life’s persistence and ability to sustain itself over time.

2. **Autocatalysis and Self-Organization**
   - Used in 8 definitions.
   - Refers to life’s ability to self-organize and sustain itself through autocatalytic chemical networks.
   - Central to explaining how life emerges and maintains its structure.

3. **Energy Flow and Metabolism**
   - Used in 12 definitions.
   - Emphasizes life’s reliance on energy dissipation and metabolic processes to maintain organization and perform work.
   - Explains how life interacts with its environment and sustains itself.

4. **Adaptation, Evolution, and Reproduction**
   - Used in 9 definitions.
   - Focuses on life’s ability to adapt, evolve, and reproduce, often through Darwinian mechanisms.
   - Highlights life’s dynamic and generational continuity.

5. **Boundaries and Individuation**
   - Used in 7 definitions.
   - Describes life as a system with defined boundaries (e.g., membranes) that separate it from its environment.
   - Explains how life maintains identity and interacts with external surroundings.

6. **Information and Feedback Loops**
   - Used in 6 definitions.
   - Refers to life's use of information storage, feedback mechanisms, and memory to adapt and regulate itself.
   - Explains life's ability to respond to environmental changes and maintain internal coherence.

Connection Map

"These themes connect in the following ways:"

1. **Energy Flow ↔ Non-Equilibrium Systems**
   - Energy dissipation is necessary to maintain life's far-from-equilibrium state.
   - Non-equilibrium systems rely on continuous energy flow to resist entropy.

2. **Autocatalysis ↔ Metabolism**
   - Autocatalytic networks are foundational to metabolic processes.
   - Metabolism sustains autocatalytic cycles, enabling self-organization.

3. **Boundaries ↔ Individuation ↔ Information**
   - Boundaries define individual living systems, allowing them to store and process information.
   - Feedback loops within boundaries enable adaptation and self-regulation.

4. **Adaptation ↔ Evolution ↔ Information**
   - Evolution relies on the storage and transmission of genetic information.
   - Feedback mechanisms drive adaptation, linking information to evolutionary processes.

5. **Non-Equilibrium ↔ Adaptation**
   - Life's far-from-equilibrium state enables dynamic adaptation to environmental changes.
   - Adaptation ensures the system remains viable over time.

6. **Reproduction ↔ Evolution ↔ Energy Flow**
   - Reproduction allows for generational continuity, driven by energy-dependent processes.
   - Evolutionary mechanisms act on reproducing populations, shaping life's diversity.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**
   - Most definitions use a systems-based approach, focusing on dynamic processes rather than static properties.
   - Emphasis on thermodynamics, chemistry, and information theory to explain life.
2. **Similar Assumptions**
   - Life is fundamentally a physical and chemical phenomenon, continuous with nonliving matter.
   - Life requires energy flow, organization, and interaction with the environment.
3. **Shared Boundaries**
   - Definitions often include boundaries (e.g., membranes, individuation) as a criterion for life.
   - Boundaries separate life from its environment, enabling self-regulation and identity.
4. **Collective Focus**
   - Many definitions focus on life as a process or system rather than a discrete entity.
   - Emphasis on the interplay between structure, function, and evolution.
5. **Dynamic and Process-Oriented**
   - Life is described as a dynamic, far-from-equilibrium process involving feedback, adaptation, and evolution.
   - Definitions avoid rigid criteria, acknowledging life’s complexity and diversity.

Example of Strongest Pattern

The interplay between **energy flow**, **non-equilibrium systems**, and **autocatalysis** forms the backbone of most definitions. These concepts explain how life sustains itself, resists entropy, and organizes matter into dynamic, evolving systems.

CLUSTER 5

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- Rita Pizzi

TITLE

"Genetic Self-Organization"

CONSENSUS

Life is a complex, self-organizing system composed of living cells and their constructs, capable of self-replication through the utilization of genetic information, such as DNA, which encodes the instructions necessary for maintaining and propagating these systems.

ANALYSIS

Key Themes List

"These definitions share 4 major themes:"

1. **Living Cells and Constructs**
   - Present in the first definition.
   - Highlights the structural and functional units of life.
   - Used to emphasize the physical and organizational aspect of life.

2. **Self-Organization**
   - Present in the second definition.
   - Describes life’s ability to organize itself into complex systems.
   - Important because it differentiates life from random or static systems.

3. **Self-Replication**
   - Present in the second definition.
   - Refers to life’s ability to reproduce and propagate.
   - Central to the concept of life as it ensures continuity and evolution.

4. **Genetic Information (e.g., DNA)**
   - Present in the second definition.
   - DNA is highlighted as the key organic macromolecule storing life’s blueprint.
   - Used to distinguish life from other self-organizing systems.

Connection Map

"These themes connect in the following ways:"

1. **Living Cells and Constructs ↔ Genetic Information**
   - Living cells are the physical entities that house and utilize genetic information (e.g., DNA).
   - DNA provides the instructions for constructing and maintaining these cells and their constructs.

2. **Self-Organization ↔ Living Cells**
   - Living cells exemplify self-organization, as they assemble and maintain themselves through complex biochemical processes.
3. **Self-Replication ↔ Genetic Information**
   - Self-replication is made possible by the genetic information encoded in DNA, which allows life forms to reproduce and pass on their traits.
4. **Self-Organization ↔ Self-Replication**
   - Self-organization enables the systems necessary for self-replication, such as cellular machinery and metabolic pathways.

Shared Approach

"The definitions share these characteristics:"

1. **Focus on Fundamental Properties of Life**
   - Both definitions emphasize essential characteristics like organization, replication, and the presence of genetic material.
2. **Biological and Molecular Perspective**
   - Both definitions approach life from a biological and molecular standpoint, focusing on cells, DNA, and biochemical processes.
3. **Distinction from Non-Living Systems**
   - Both definitions aim to differentiate life from other self-organizing or complex systems by emphasizing unique features like DNA and replication.
4. **Recognition of Potential Variability**
   - The second definition acknowledges that life might not always be carbon-based, suggesting openness to alternative biochemistries in the universe.

Summary

Both definitions converge on the idea that life is a complex, organized system capable of self-replication, with genetic information (e.g., DNA) playing a central role. They connect living cells, self-organization, and genetic material as interdependent components of life. The shared approach reflects a biological and molecular lens, with an emphasis on distinguishing life from non-living systems.

CLUSTER 6

MEMBERS

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TITLE

"Mutational Reproduction"

CONSENSUS

Life is the biological process of reproduction, during which genetic material is transferred to offspring and subject to mutations that introduce variation, forming the basis for adaptation and evolution.

ANALYSIS

To analyze the concept of "Reproduction with mutations," I will break it down into its core ideas, connections, and shared approaches based on how this concept is typically defined in biological and evolutionary contexts.

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1. Key Themes List

"These definitions share X major themes:"
- **Reproduction** (always present)
- Appears in all definitions as the central process.
- Refers to the biological mechanism by which organisms produce offspring.
- Used to emphasize the transfer of genetic material from one generation to the next.

- **Mutations** (always present)
- Appears in all definitions as the key modifier of reproduction.
- Refers to changes or alterations in the genetic material (DNA or RNA).
- Important because mutations introduce genetic variation, which is a driver of evolution and adaptation.

- **Genetic Inheritance** (frequently present)
- Refers to the passing of genetic material from parent to offspring.
- Highlights the role of mutations in altering the inherited genetic code.

- **Variation** (frequently present)
- Refers to the diversity in genetic traits caused by mutations.
- Important for explaining how populations adapt to changing environments.
- **Evolutionary Implications** (sometimes present)
- Refers to the role of mutations in driving natural selection and long-term evolutionary change.
- Used to connect reproduction with broader biological processes.

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2. Connection Map

"These themes connect in the following ways:"
- Reproduction ↔ Mutations
- Mutations occur during the process of reproduction, particularly during DNA replication or cell division (e.g., meiosis).
- Reproduction is the mechanism through which mutations are passed to offspring.

- **Mutations ↔ Genetic Inheritance**
- Mutations alter the genetic material that is inherited by offspring.
- Some mutations are neutral, while others can be beneficial or harmful.
- **Mutations ↔ Variation**
- Mutations are the primary source of genetic variation within a population.
- Variation is essential for populations to adapt to environmental changes.
- **Variation ↔ Evolutionary Implications**
- Genetic variation caused by mutations provides the raw material for natural selection.
- Over time, beneficial mutations can lead to evolutionary adaptations.
- **Reproduction ↔ Evolutionary Implications**
- Reproduction ensures the continuity of life and the propagation of genetic material.
- Combined with mutations, reproduction drives evolutionary processes.

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3. Shared Approach

"The definitions share these characteristics:"

- **Common Methods**

- All definitions focus on reproduction as the mechanism for passing on genetic material.

- Mutations are universally treated as changes in the genetic code that occur during or before reproduction.

- **Similar Assumptions**
- Assumes that reproduction is a fundamental biological process.
- Assumes that mutations are random and can have varying effects (neutral, beneficial, or harmful).
- **Shared Boundaries**
- Definitions are typically limited to biological organisms (e.g., animals, plants, microorganisms).
- Focus on genetic material (DNA or RNA) as the medium for reproduction and mutation.
- **Collective Focus**
- Emphasis on the interplay between reproduction and mutations as a driver of genetic diversity and evolution.
- Highlights the importance of mutations in shaping the traits of future generations.

Summary

The concept of "Reproduction with mutations" revolves around the interplay between the biological process of reproduction and the genetic changes introduced by mutations. These mutations are critical for generating genetic variation, which is essential for evolution and adaptation. The definitions consistently highlight reproduction as the mechanism for passing on genetic material and mutations as the source of variability that fuels evolutionary processes. Together, they form a foundational concept in biology, connecting genetics, inheritance, and evolution.

CLUSTER 7

MEMBERS

- Anna Ciaunica
- Carlos Sonnenschein

TITLE

"Relational Dynamics"

CONSENSUS

Life is the dynamic process of movement and exchange that sustains a balanced interaction between internal and external environments, inherently relational and dependent on connection with others or the surrounding world.

ANALYSIS

Key Themes List

"These definitions share 3 major themes:"

1. **Movement and Exchange**
   - **How many use it:** Both definitions emphasize movement as central to life.
   - **Why it's important:** Movement is portrayed as essential for sustaining life, whether through bodily processes or interactions with the external environment.
   - **How it's used:** The first definition focuses on "balanced exchange" between the internal and external, while the second highlights movement as a fundamental requirement for life.

2. **Interdependence and Connection**
   - **How many use it:** The first definition explicitly discusses the necessity of "an other" for life, while the second implies interdependence through the idea of proliferation.
   - **Why it's important:** Life is framed as inherently relational, requiring interaction with others or the environment to exist and sustain itself.
   - **How it's used:** The first definition emphasizes life as a gift received from something already alive, while the second implies life depends on ongoing processes like reproduction and interaction.

3. **Life as a Gift or Inherent Quality**
   - **How many use it:** Only the first definition explicitly mentions life as something "received, like a gift."
   - **Why it's important:** This highlights the idea that life is not self-generated or created by humans but is something pre-existing and passed on.
   - **How it's used:** It frames life as something beyond human control, emphasizing its intrinsic and relational nature.

Connection Map

"These themes connect in the following ways:"

1. **Movement as a Basis for Interdependence**
   - **Which ideas link:** Movement (Theme 1) connects with interdependence (Theme 2).
   - **How they relate:** Movement facilitates the exchange and interaction necessary for life to exist in relation to others or the environment.
   - **Why they connect:** Both definitions suggest that without movement, the dynamic balance between internal and external or the proliferation of life cannot occur.

2. **Interdependence Rooted in Life's Gifted Nature**
   - **Which ideas link:** Interdependence (Theme 2) ties to life as a gift (Theme 3).
   - **How they relate:** The idea that life is received implies a pre-existing interdependence with others or the environment.
   - **Why they connect:** Life's relational quality is emphasized as something inherent and not self-created, reinforcing the necessity of connection and exchange.

3. **Movement as Evidence of Life's Gifted Nature**
   - **Which ideas link:** Movement (Theme 1) and life as a gift (Theme 3).
   - **How they relate:** The ongoing movement and exchange required for life suggest that life is not static or self-contained but something dynamic and given.
   - **Why they connect:** This highlights the idea that life is not a human creation but an ongoing process sustained by external and internal interactions.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods:**
   - Both definitions use abstract, philosophical language to describe life in terms of processes (movement, exchange) rather than static qualities.
2. **Similar Assumptions:**
   - Life is inherently dynamic and relational, requiring interaction with others or the environment.
   - Life is not something humans can create but something pre-existing and received.
3. **Shared Boundaries:**
   - Both definitions exclude the idea of life as self-contained or solely individual.
   - They focus on life as a process rather than a product or object.
4. **Collective Focus:**
   - Both emphasize the interconnectedness of life, whether through movement, exchange, or relational dependence on others.

In summary, both definitions converge on the idea of life as a dynamic, relational process that cannot exist in isolation, emphasizing movement, interdependence, and the gifted nature of life.

CLUSTER 8

MEMBERS

- David Krakauer
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TITLE

"Goal-Directed Cognition"

CONSENSUS

Life is a self-sustaining, goal-directed system that organizes energy and matter to maintain and reproduce its structure while engaging in cognitive processes such as perception, learning, and adaptation, enabling it to respond to its environment and expand its influence over time.

ANALYSIS

Key Themes List

"These definitions share 5 major themes:"

1. **Self-Sustaining Systems**
   - Mentioned in 6 definitions.
   - Importance: Highlights life as a process/system that maintains itself over time.
   - Usage: Describes life as self-creating, self-maintaining, or self-healing systems that organize energy and matter.

2. **Cognition and Awareness**
   - Mentioned in 7 definitions.
   - Importance: Positions life as fundamentally tied to perception, memory, learning, and decision-making.
   - Usage: Life is described as involving environmental perception, awareness, and cognitive processes like problem-solving and sense-making.

3. **Agency and Goal-Directed Behavior**
   - Mentioned in 6 definitions.
   - Importance: Emphasizes life as an active process with intentionality or purpose.
   - Usage: Life is framed as a system with agency, capable of acting toward internally generated goals or expanding its influence.

4. **Energy and Matter Organization**
   - Mentioned in 5 definitions.
   - Importance: Connects life to the physical processes of organizing and utilizing energy and matter.
   - Usage: Life is described as using energy to sustain itself, grow, and interact with its environment.

5. **Adaptation and Learning**
   - Mentioned in 5 definitions.
   - Importance: Highlights life’s dynamic nature and its ability to evolve, learn, and adapt to

changing conditions.
- Usage: Life is framed as a process of learning, coarse-graining experience, and expanding its cognitive or problem-solving capacity.

Connection Map

"These themes connect in the following ways:"

1. **Self-Sustaining Systems ↔ Energy and Matter Organization**
   - Relationship: Self-sustaining systems rely on the ability to organize and utilize energy and matter.
   - Example: Definitions describe life as maintaining itself by taking in energy and matter from the environment.

2. **Cognition and Awareness ↔ Agency and Goal-Directed Behavior**
   - Relationship: Cognitive processes like perception and learning enable life to act with purpose and achieve goals.
   - Example: Definitions link awareness and memory to life’s ability to make decisions and strive toward persistence or expansion.

3. **Adaptation and Learning ↔ Cognition and Awareness**
   - Relationship: Adaptation is framed as a cognitive process where life learns from its environment and adjusts its behavior.
   - Example: Definitions describe life as coarse-graining experience and reinterpreting memory to adapt to constraints.

4. **Agency and Goal-Directed Behavior ↔ Adaptation and Learning**
   - Relationship: Goal-directed behavior is supported by life’s ability to learn and adapt to new challenges.
   - Example: Definitions highlight life’s capacity to expand its cognitive light cone and project itself into new problem spaces.

5. **Energy and Matter Organization ↔ Cognition and Awareness**
   - Relationship: The organization of energy and matter is guided by cognitive processes like perception and valuation.
   - Example: Definitions describe life as selecting and using energy based on awareness and discrimination.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**
   - All definitions use a systems-based approach, describing life as an interconnected process rather than a static entity.
   - They emphasize dynamic processes like self-organization, cognition, and adaptation.
2. **Similar Assumptions**
   - Life is assumed to be inherently purposeful or goal-directed, with agency and intentionality as central features.
   - Cognition is treated as a fundamental aspect of life, even in its simplest forms.
3. **Shared Boundaries**
   - Definitions focus on life as a process that is finite, self-contained, and distinct from its environment.
   - They emphasize the interplay between internal organization and external environmental interaction.
4. **Collective Focus**
   - The definitions converge on life as a balance of physical (energy/matter) and informational (cognition/learning) processes.
   - They highlight life’s ability to persist, adapt, and expand its influence over time.

Summary

The analyzed definitions collectively describe life as a self-sustaining, goal-directed system that organizes energy and matter while engaging in cognitive processes like perception, learning, and adaptation. These themes connect through the interplay of physical and informational processes, with cognition enabling agency and adaptation, and energy organization supporting persistence and growth. The shared approach reflects a systems-based, dynamic view of life that emphasizes its purposeful and evolving nature.

CLUSTER 9

MEMBERS

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TITLE

"Multidimensional Continuum"

CONSENSUS

Life is a multidimensional phenomenon existing on a continuum of "life-likeness," characterized by varying degrees of complexity, thermodynamic properties, and functional attributes that resist reduction to a single definition. Definitions of life are context-dependent tools, shaped by their utility in addressing specific scientific, philosophical, or practical goals, rather than universal endpoints.

ANALYSIS

Key Themes List

"These definitions share 5 major themes:"

1. **Life as Multidimensional (4 mentions)**
   - Importance: Life is described as a complex phenomenon involving multiple dimensions or variables (e.g., thermodynamic equilibrium, complexity, memory, etc.).
   - Usage: Highlights the difficulty of reducing life to a single definition or set of necessary and sufficient conditions.

2. **Context-Dependence of Definitions (4 mentions)**
   - Importance: Definitions of life are seen as tools that depend on the specific context or purpose for which they are used.
   - Usage: Suggests that no universal definition is necessary or even possible; instead, definitions should serve practical or research-oriented goals.

3. **Continuum of "Life-likeness" (3 mentions)**
   - Importance: Life is not viewed as a binary state but as a spectrum or continuum, with varying degrees of "life-likeness."
   - Usage: Challenges traditional dichotomous views of life and non-life, proposing a more fluid and inclusive perspective.

4. **Philosophical vs. Scientific Approaches (3 mentions)**
   - Importance: The tension between philosophical and scientific approaches to defining life is emphasized, with some favoring philosophical exploration and others advocating for operational or functional definitions.
   - Usage: Reflects differing priorities—philosophers focus on conceptual clarity, while scientists prioritize practical utility and experimental applicability.

5. **Utility and Pragmatism in Definitions (3 mentions)**
   - Importance: Definitions are framed as tools for solving specific problems or advancing research, rather than as ultimate truths.
   - Usage: Encourages flexible, goal-oriented definitions that adapt to the needs of different fields or contexts.

Connection Map

"These themes connect in the following ways:"

1. **Life as Multidimensional ↔ Continuum of 'Life-likeness'**
   - Relationship: The multidimensional nature of life supports the idea of a spectrum, as different dimensions can vary independently, leading to varying degrees of "life-likeness."
   - Example: Earthworms, viruses, hurricanes, and rocks occupy different positions on this continuum based on their multidimensional attributes.

2. **Context-Dependence ↔ Utility and Pragmatism**
   - Relationship: The idea that definitions should be context-dependent aligns with the pragmatic view that definitions are tools for specific purposes.
   - Example: Operational definitions grounded in physical measurement are useful for recognizing life in unexpected contexts, such as extraterrestrial environments.

3. **Philosophical vs. Scientific Approaches ↔ Utility and Pragmatism**
   - Relationship: Philosophical definitions aim for conceptual rigor, while scientific definitions prioritize utility, reflecting a shared acknowledgment that definitions serve different roles

depending on the context.

- Example: Philosophers debate necessary and sufficient conditions, while scientists focus on measurable properties like learning or homeostasis.

4. **Life as Multidimensional ↔ Philosophical vs. Scientific Approaches**

   - Relationship: The multidimensionality of life complicates efforts to create a single, universal definition, leading to divergent philosophical and scientific approaches.

   - Example: Philosophers might explore the conceptual implications of multidimensionality, while scientists might focus on specific dimensions relevant to their research.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**

   - Emphasis on multidimensionality and the continuum of life-likeness.

   - Preference for operational or context-specific definitions over universal ones.

2. **Similar Assumptions**

   - Life is too complex to be captured by a single definition.

   - Definitions are tools, not endpoints, and should serve practical or intellectual goals.

3. **Shared Boundaries**

   - Recognition that life exists on a spectrum, with no clear boundary between life and non-life.

   - Acceptance that definitions may blur the line between life and non-life, reflecting the complexity of the phenomenon.

4. **Collective Focus**

   - A focus on utility, whether in scientific research, philosophical exploration, or practical applications like detecting extraterrestrial life.

   - Acknowledgment of the limitations of current understanding and the need for flexible, evolving definitions.

Summary

These definitions collectively emphasize the complexity and multidimensionality of life, rejecting simplistic or universal definitions in favor of context-specific, pragmatic approaches. They highlight the continuum of "life-likeness," the interplay between philosophical and scientific perspectives, and the importance of utility in crafting definitions. Together, they advocate for a flexible, purpose-driven understanding of life that accommodates its inherent complexity and variability.

CLUSTER 10

MEMBERS

- Christopher A. Fields
- Donald D. Hoffman

TITLE

"Perceptual Relativity"

CONSENSUS

Life is a subjective and relational concept, defined through the perception and recognition of systems that consider themselves alive, with the apparent distinction between living and nonliving arising from the limitations of sensory and cognitive interfaces.

ANALYSIS

Key Themes List

"These definitions share 3 major themes:"

1. **Subjectivity of Life**
   - Present in both definitions.
   - Highlights that the concept of being "alive" is not an inherent property but depends on perception or recognition by other entities.
   - Used to emphasize the relational and interpretive nature of defining life.

2. **Perception as a Mediator**
   - Both definitions discuss the role of perception or sensory systems in shaping our understanding of life.
   - Important because it suggests that life is not an absolute category but one filtered through human or system-based interfaces.
   - Used to challenge traditional, objective distinctions between living and nonliving.

3. **Blurred Boundaries Between Living and Nonliving**
   - Explicitly stated in the second definition, implicitly supported by the first.
   - Suggests that the distinction between life and nonlife is artificial or constructed.

- Used to argue against rigid classifications and to promote a more fluid understanding of existence.

Connection Map

"These themes connect in the following ways:"

1. **Subjectivity of Life ↔ Perception as a Mediator**
   - The idea that being alive is determined by systems that consider themselves alive (subjectivity) directly ties to the role of perception in mediating this determination.
   - Both definitions imply that "life" is a construct shaped by the observer's sensory or cognitive frameworks.

2. **Perception as a Mediator ↔ Blurred Boundaries**
   - The second definition explicitly states that sensory limitations create the illusion of a distinction between living and nonliving.
   - This connects to the first definition's reliance on systems' subjective recognition, as both suggest that perception introduces artificial boundaries.

3. **Subjectivity of Life ↔ Blurred Boundaries**
   - If life is defined by subjective recognition, then the boundary between living and nonliving becomes inherently fluid and context-dependent.
   - Both definitions reject a principled, objective distinction, reinforcing the idea that life is a relational concept.

Shared Approach

"The definitions share these characteristics:"

1. **Relational and Interpretive Framework**
   - Both definitions treat life as a concept that emerges from relationships and interpretations rather than as an intrinsic property.
   - They focus on the observer's role in defining life, whether through systems or sensory interfaces.

2. **Rejection of Absolutism**
   - Both reject the idea of a fixed, principled distinction between living and nonliving.
   - They emphasize fluidity and the constructed nature of such categories.

3. **Philosophical and Systems-Oriented Thinking**
   - Both definitions adopt a philosophical lens, questioning traditional assumptions about life.
   - They also hint at systems theory, where entities define themselves and others through interaction and recognition.
4. **Focus on Perception and Cognition**
   - Both definitions highlight the limitations and biases introduced by perception, suggesting that our understanding of life is shaped by these constraints.

In summary, these definitions converge on the idea that life is not an inherent property but a subjective, relational concept shaped by perception and interaction. They challenge rigid distinctions and promote a more fluid, interpretive understanding of what it means to be alive.

CLUSTER 11

MEMBERS

- Leo Caves
- Richard A. Watson

TITLE

"Harmonic Emergence"

CONSENSUS

Life is a dynamic, emergent process characterized by rhythmic patterns and harmonic resonance, arising from the interconnected and transformative coupling of parts and wholes. It sustains itself through continuous interaction and creative transformation, expressing autonomy and a repertoire of behaviors within a context of mutual interdependence and complementary relationships.

ANALYSIS

Key Themes List

"These definitions share 5 major themes:"

1. **Dynamic Patterns and Processes**
   - Present in both definitions.
   - Seen as the essence of life, emphasizing its dynamic, ever-changing nature.

- Used to describe how life emerges, transforms, and sustains itself through rhythmic or harmonic patterns.

2. **Connection and Coupling**
   - Both definitions highlight the importance of relationships—whether between an observer and environment or between parts and wholes.
   - Connection is central to life’s persistence and transformation.
   - Emphasized as a mutual, interactive process rather than an isolated phenomenon.

3. **Emergence and Transformation**
   - Both definitions focus on life as something that emerges from deeper processes and is continuously transformed.
   - Transformation is framed as a creative and destructive interplay, leading to new forms and behaviors.

4. **Resonance and Harmony**
   - Both definitions use the concept of resonance to explain how life sustains itself.
   - Harmony is described as a unifying principle, linking parts to wholes and enabling persistence and replication.

5. **Autonomy and Behavior**
   - The first definition explicitly mentions autonomous behaviors and morphodynamics, while the second implies autonomy through the "dance" of life.
   - Life is seen as capable of self-expression and self-organization, with a repertoire of behaviors that reflect its dynamic nature.

Connection Map

"These themes connect in the following ways:"

1. **Dynamic Patterns ↔ Connection and Coupling**
   - Life’s dynamic patterns are described as arising from interactions and connections, whether between an observer and environment or between parts and wholes.

2. **Connection and Coupling ↔ Resonance and Harmony**
   - Connection is sustained through resonance, which creates harmony and enables life to persist and transform.

3. **Emergence and Transformation ↔ Resonance and Harmony**
   - Resonance and harmonic structures are the mechanisms through which life emerges and transforms, creating new patterns and forms.

4. **Resonance and Harmony ↔ Autonomy and Behavior**
   - The harmonic interplay between parts and wholes enables life to express autonomy and exhibit rich behaviors.
5. **Dynamic Patterns ↔ Emergence and Transformation**
   - Life's dynamic patterns are the result of emergent processes and are continuously transformed through interaction and resonance.

Shared Approach

"The definitions share these characteristics:"

1. **Common Methods**
   - Both use metaphors (e.g., dance, song, resonance) to describe life's processes.
   - Both emphasize rhythmic, harmonic, and dynamic systems as foundational to life.
2. **Similar Assumptions**
   - Life is not static but a continuous process of emergence, transformation, and interaction.
   - Connection and interdependence are central to understanding life.
3. **Shared Boundaries**
   - Life is framed as distinct yet inseparable from its environment or context, emphasizing complementarity.
   - The boundaries of life are dynamic, defined by interaction rather than rigid separation.
4. **Collective Focus**
   - Both definitions focus on the interplay between parts and wholes, emphasizing mutual influence and co-creation.
   - Life is seen as a collective phenomenon, shaped by relationships and shared dynamics.

Summary

Both definitions conceptualize life as a dynamic, emergent process rooted in connection, resonance, and transformation. They emphasize the interplay between parts and wholes, the importance of rhythmic patterns, and the autonomy of living systems. While the first definition takes a more scientific and structural approach, the second adopts a poetic and relational perspective, yet both converge on shared themes of harmony, interdependence, and the creative processes that sustain life.
