# A Strategy for Origins of Life Research

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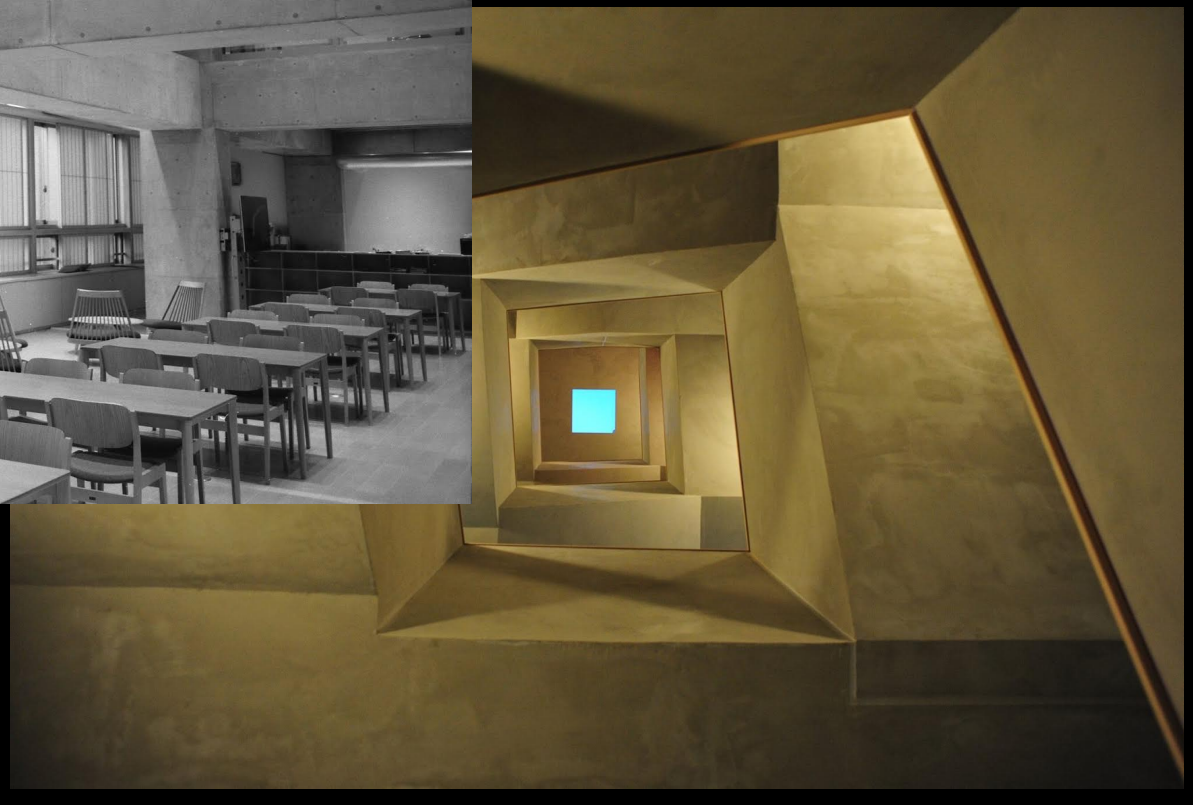
## The Earth-Life Science Institute's (ELSI) Origins Network (EON) Workshop

EARTH-LIFE SCIENCE INSTITUTE

ELSI Origins Network

東京工業大学 Tokyo Institute of Technology



# An international workshop to identify key questions and challenges in origins of life research - and new strategies

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*“All OoL studies ultimately address* ***the onset of the various organizational phenomena that we associate with the living world.”***

# A common qn with astrobiology: determining the probability function for life arising

Arguably two complementary routes to learning about abiogenesis probabilities:

Find independent examples of life

Earth
Solar System
Exoplanetary Systems

Directly evaluate likelihoods of origin mechanisms

Origins of Life (OoL) Research

# A survey of perceived key OoL issues before the meeting

## Cross-section of ‘top’ responses

What was the chronology of OoL events on the early Earth?

What were the couplings between the planetary chemical/thermodynamic environment and OoL factors such as early metabolism?

Local and global fragmentation of OoL science is an exceptional challenge, needing harmonization and synthesis.

Recognition of the need for common dialog and a cooperative community - enabling that communication in environment of limited institutional support.

How does proto-metabolism (abiotic autocatalytic cycles) connect to the putative RNA world?

Is there empirical evidence for a diversity of abiotic autocatalytic cycles other than (e.g.) the classic formose reaction?

Can we make new life (synthetic or artificial) and replace OoL with AL and design a roadmap to then solve OoL?

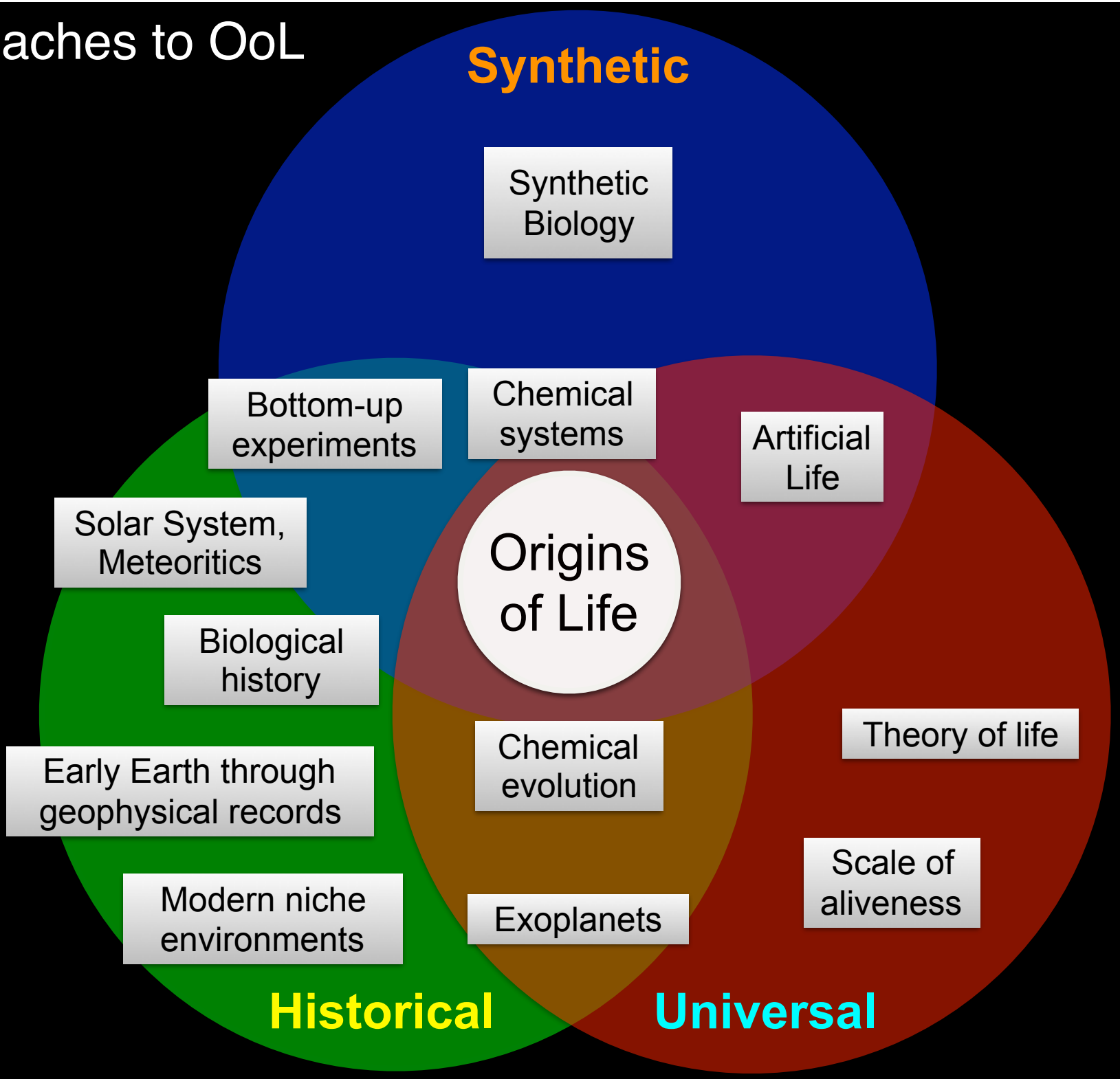
How can we improve current dogma regarding prebiotic plausibility and defining life?

Can we develop a precise knowledge of early Earth conditions and organic matter sources and availability?

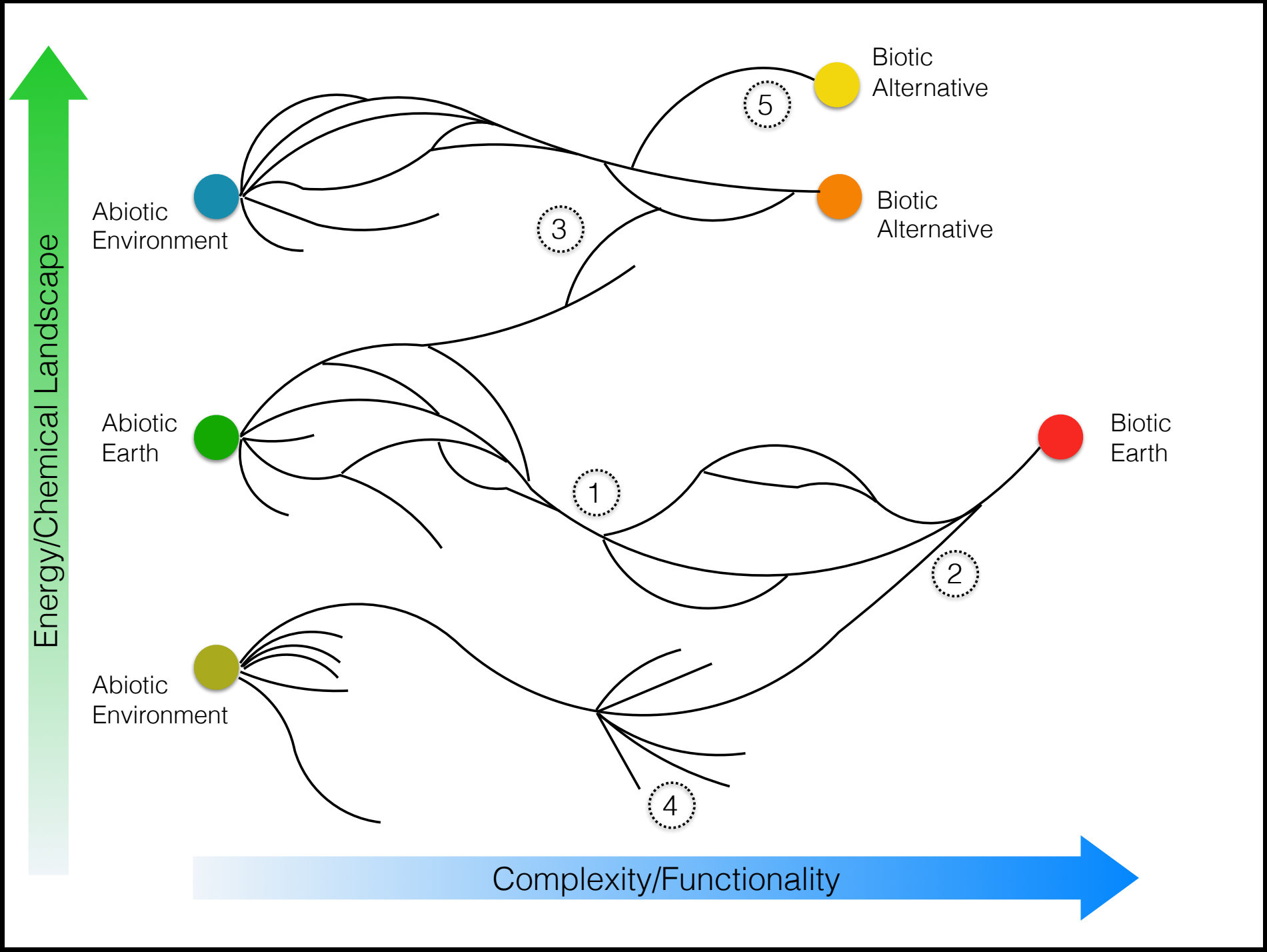
How can we perform exhaustive characterization of common minerals as prebiotic catalysts?

Are there new ways to characterize stages of life's history as information storage, processing, and transmission?

# Approaches to OoL



# One Path to Life or Many? A pathway abstraction tool



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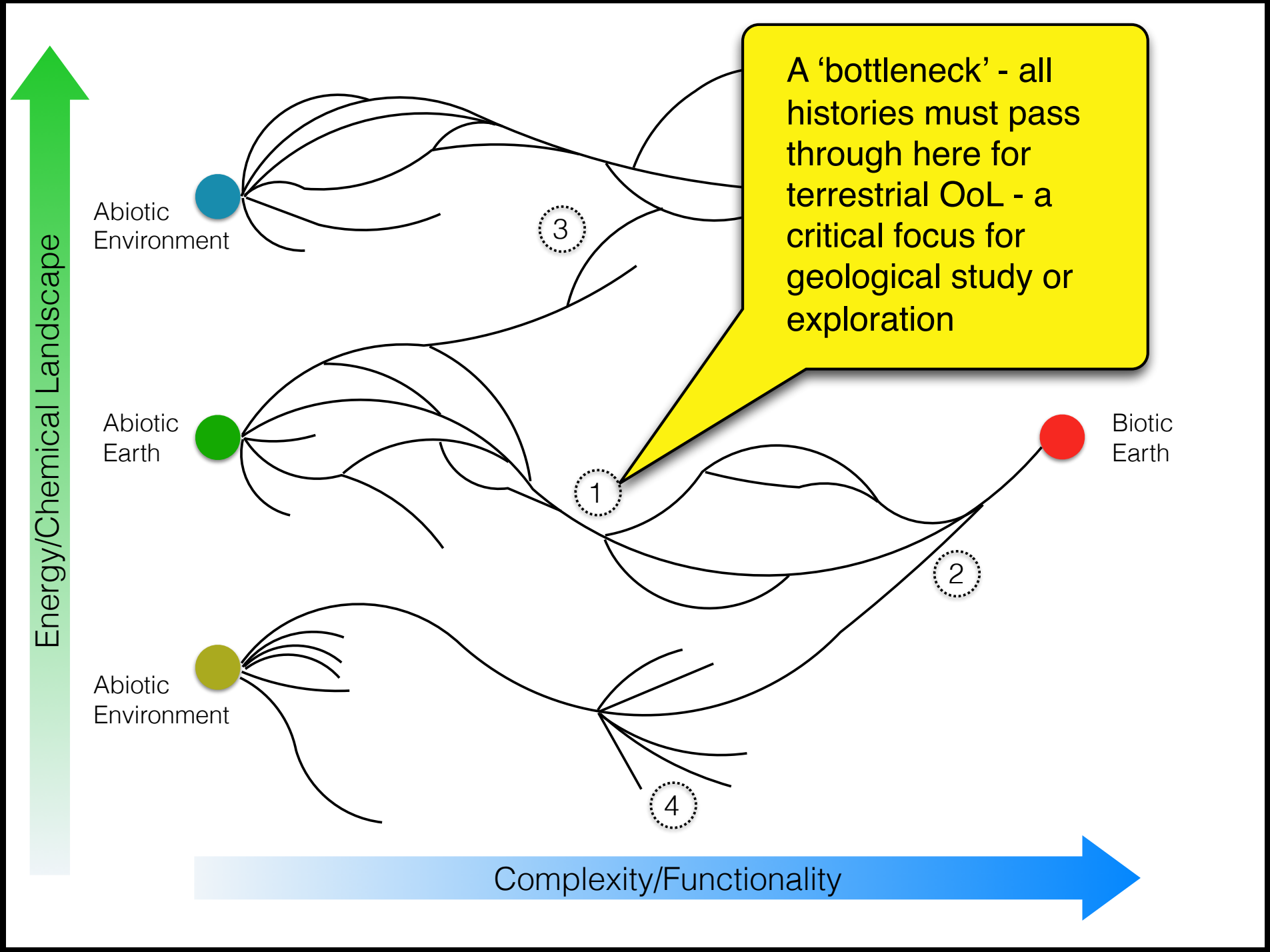

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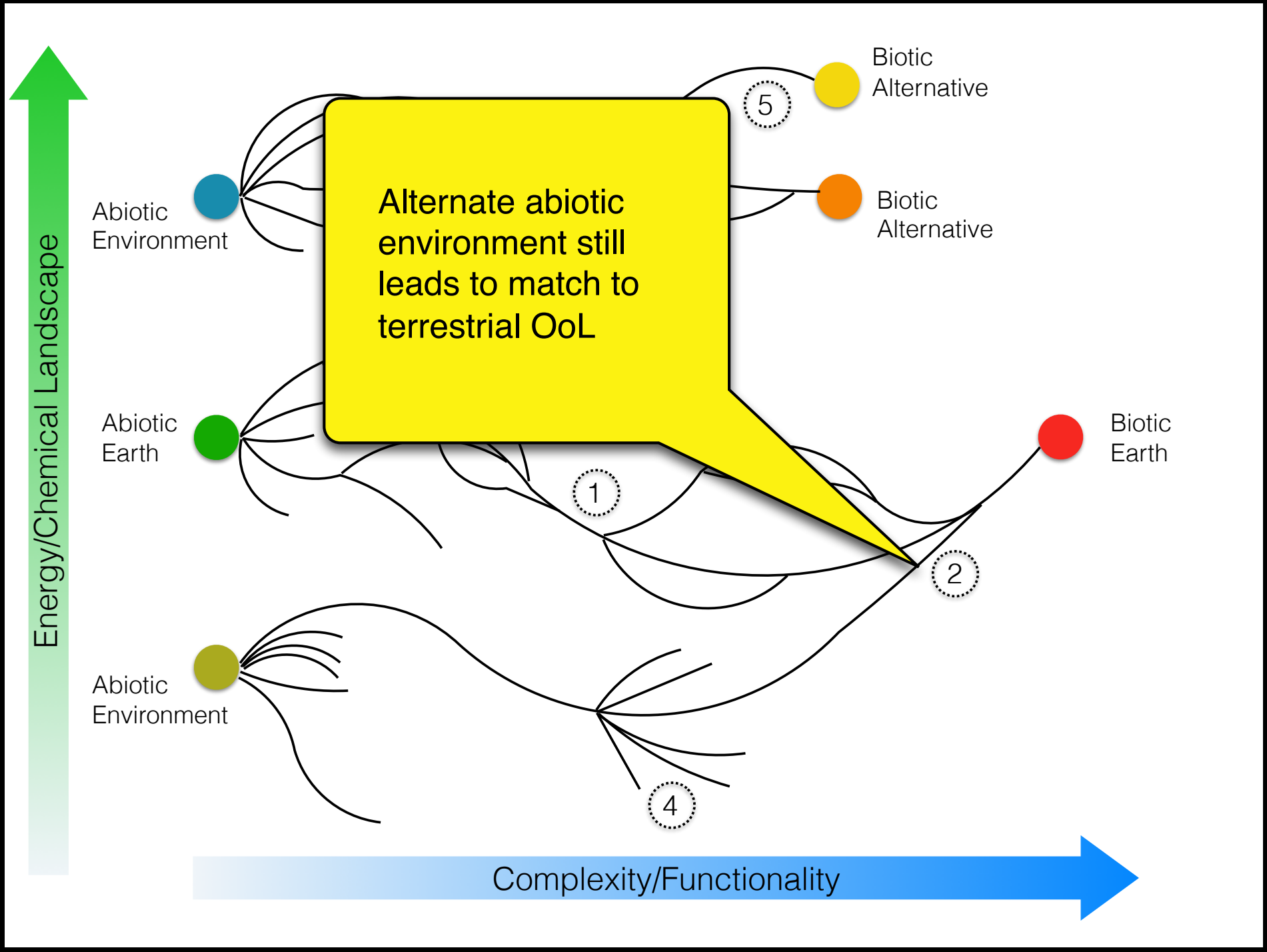

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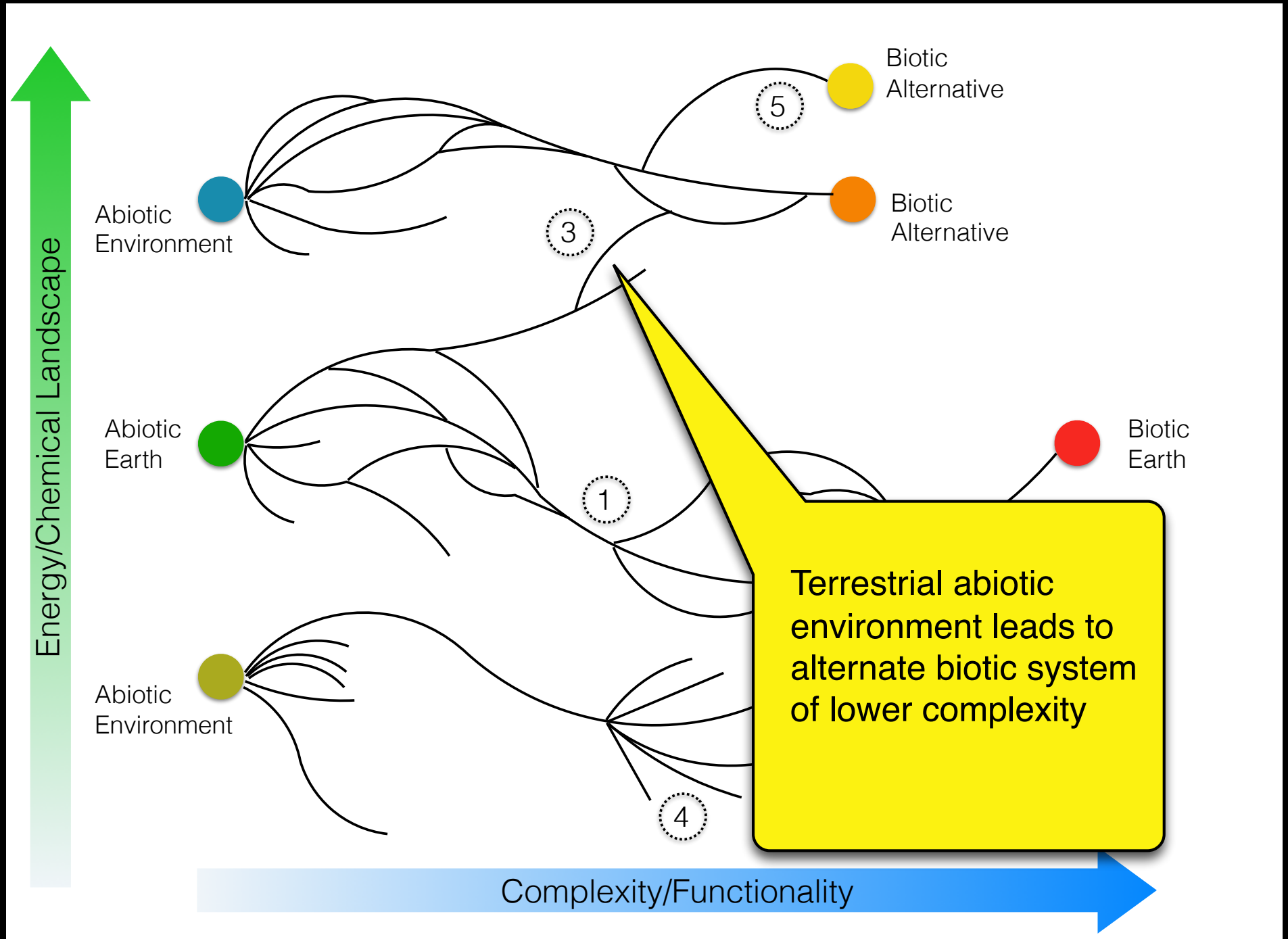

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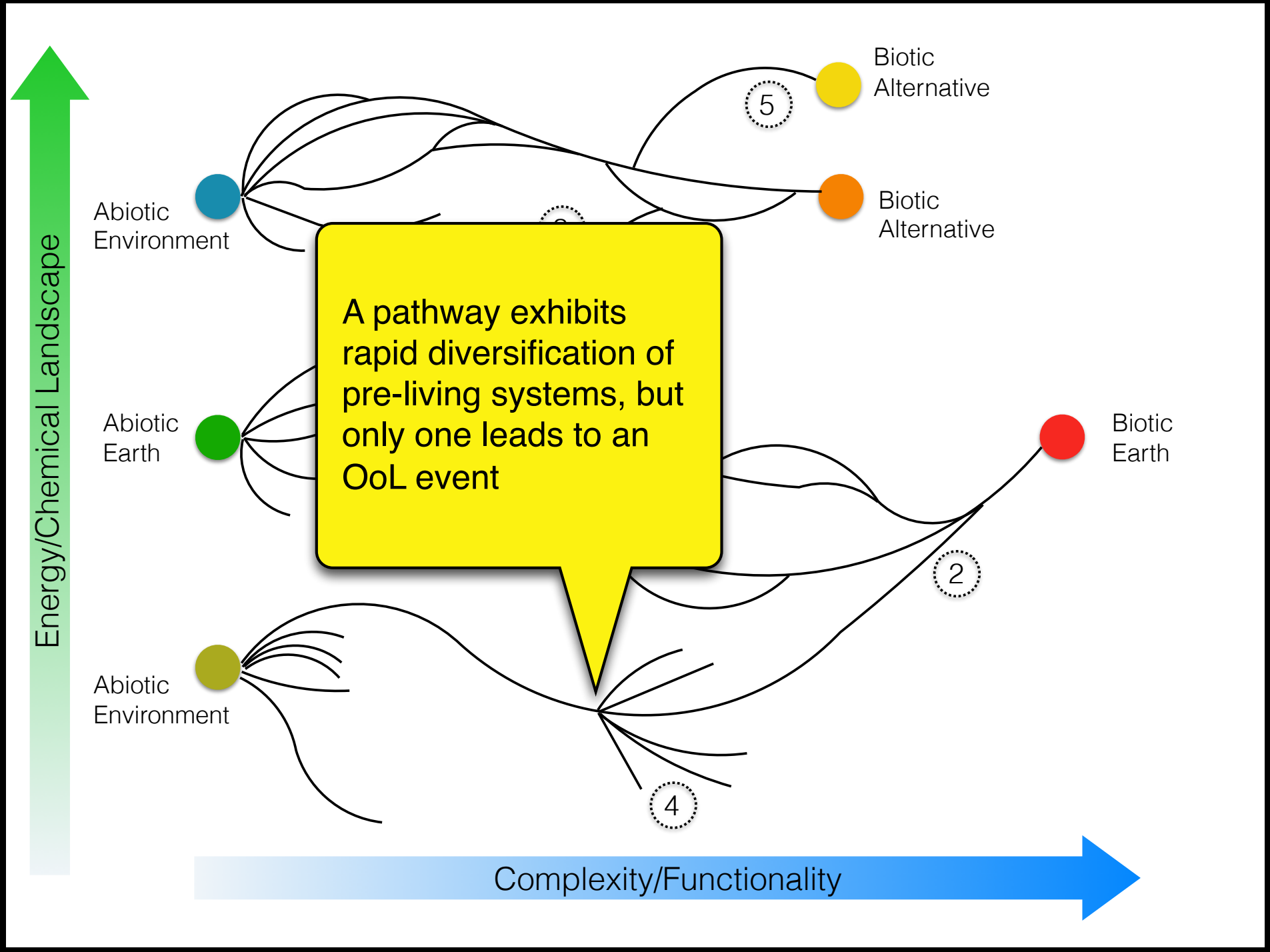

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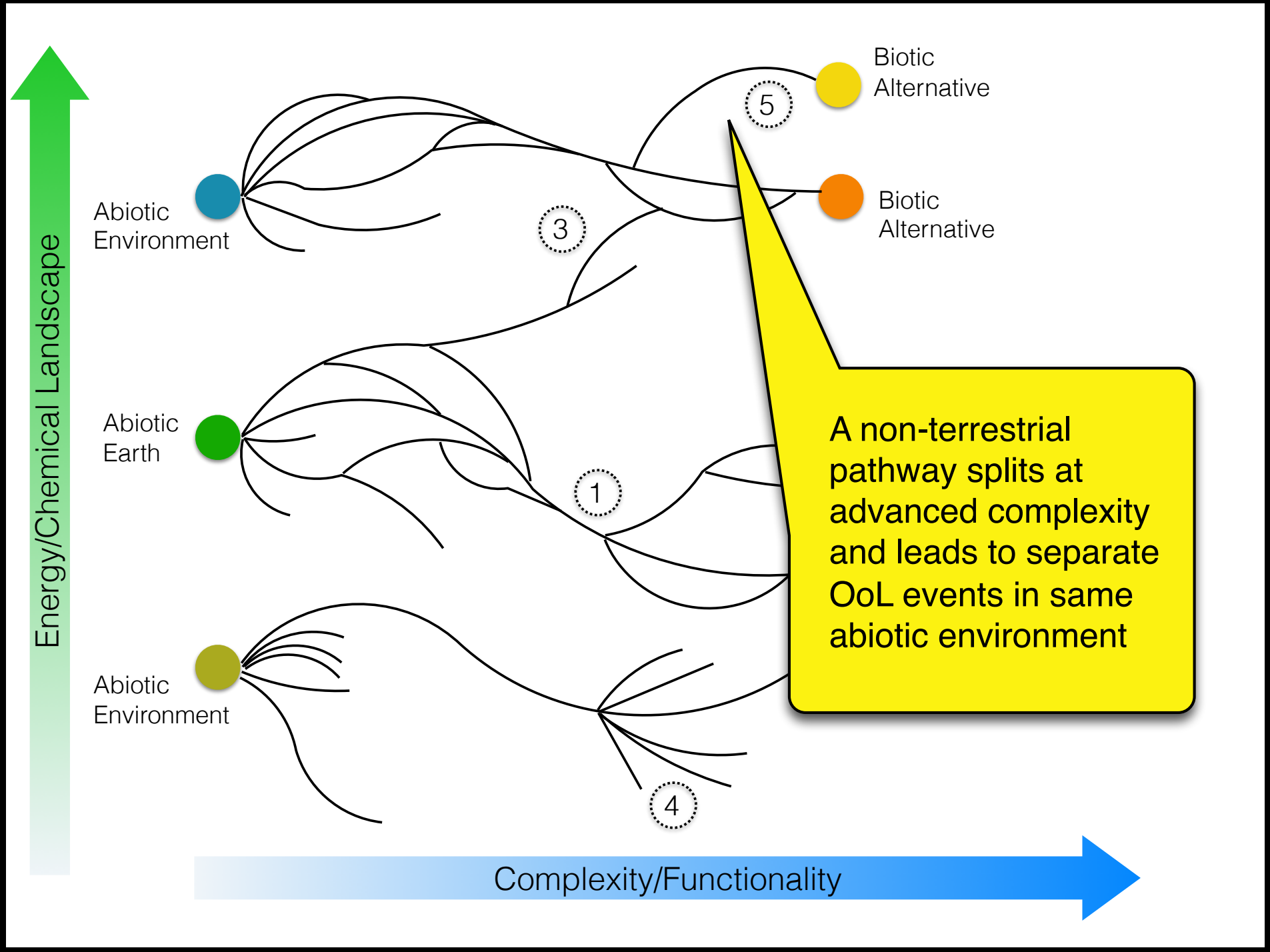
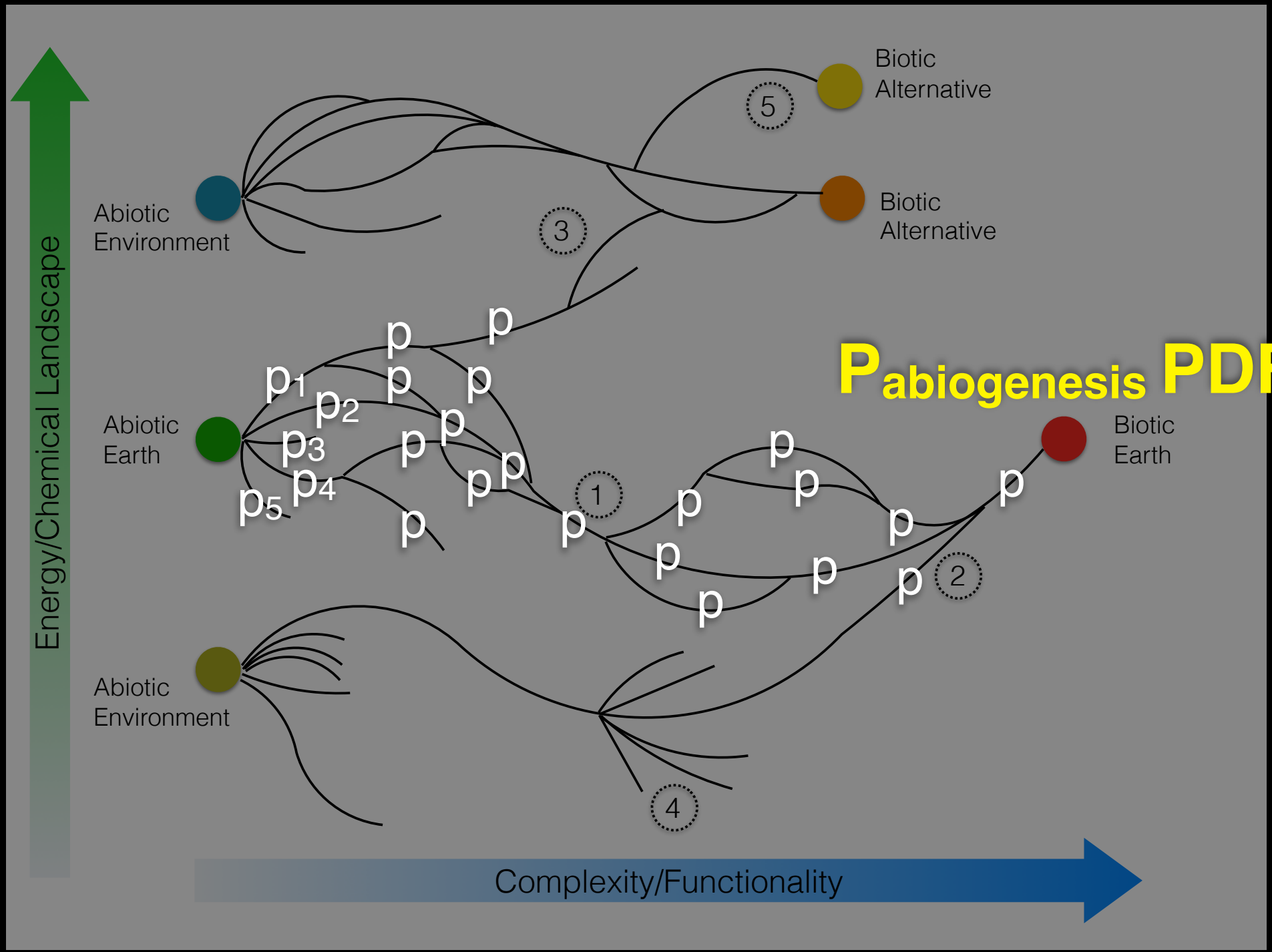


# Perhaps we can begin to assign probabilities to paths?



# Outcomes: Key Questions and Investigations

## Four Domains Identified: actionable/aspirational items

## (1) Theory

**Work on theories and definitions of life**

**Acknowledgement, and classification, of the *types* of OoL and the types of *approaches* to understanding OoL:** *e.g. Terrestrial/Actual, Extraterrestrial, Nonstandard composition/structure, Plausible, Reinvented, In silico/ Abstract.*

**An evaluation of the degree of completeness of any eventual OoL theory**

**The need for a quantitative scale of living systems:** *e.g. use of traits such as complexity, adaptiveness, thermodynamic disequilibrium.*

# Outcomes: Key Questions and Investigations

Four Domains Identified: actionable/aspirational items

## (2) Practice

**The further development of machine-chemistry-algorithm investigations:** *high-throughput, 'cyber-chemistry'.*

**Learning about the robustness of living systems by mimicry:** *robotics, social systems*

**Long term experiments**

**Organized competitions as drivers of discovery and community (OoL X-Prize?)**

# Outcomes: Key Questions and Investigations

## Four Domains Identified: actionable/aspirational items

### (3) Process

**'Safe harbors' needed for OoL science (e.g. ELSI/EON)** *i.e. researchers should not assume all risk.*

**The need to build dialog between various sub-communities** *(e.g. between traditional OoL and ALife)*

# Outcomes: Key Questions and Investigations

Four Domains Identified: actionable/aspirational items

(4) Future Studies

**Investigations targeting OoL-planetary-cosmos connections:** *e.g. early Earth, Mars, meteoritics*

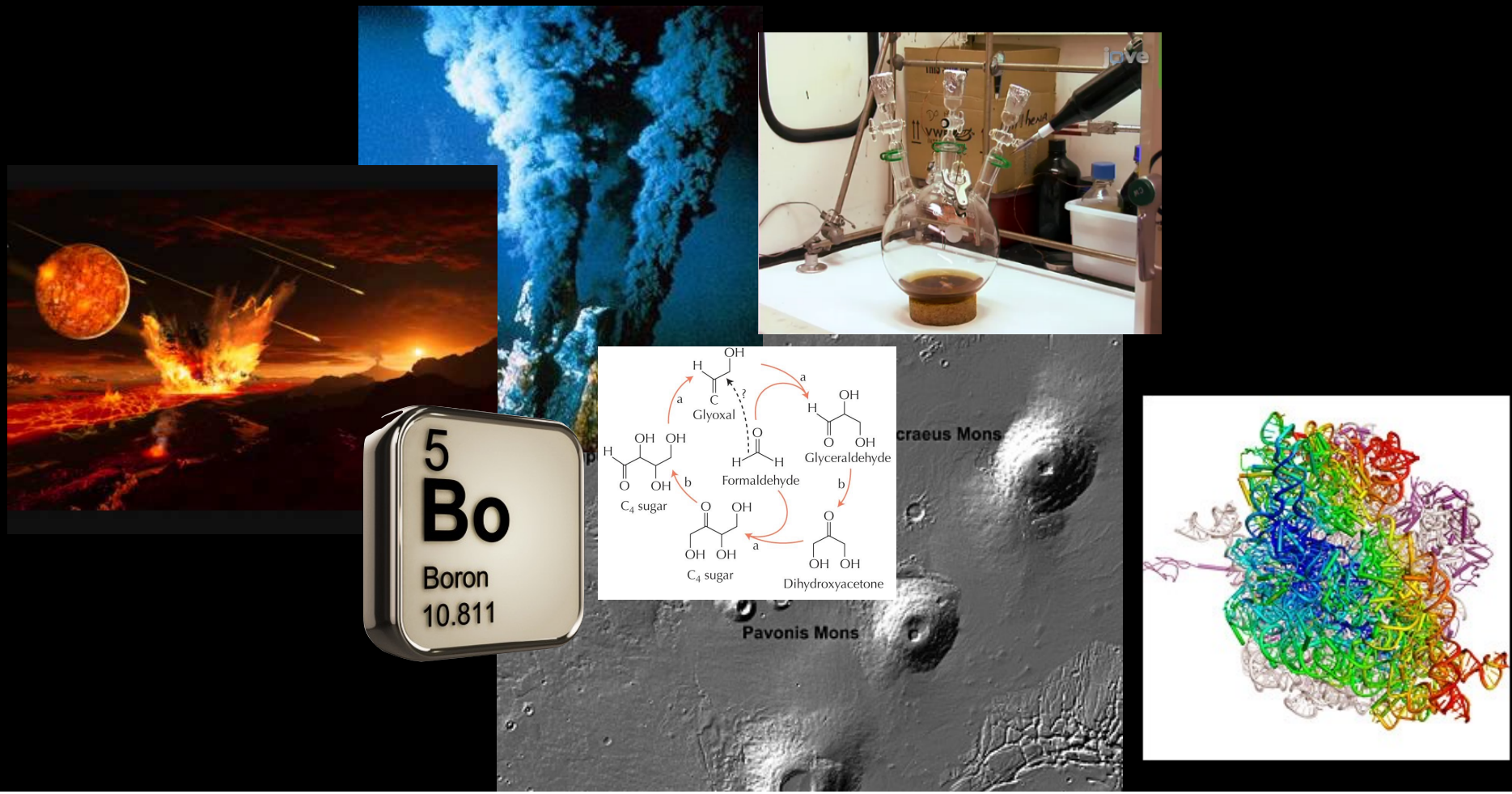
**Metabolic pathways, energy, and biology**

**Making life in the laboratory**

**Guiding the next generation of OoL scientists**

# Personal observations

There is a desperate need to move away from the ‘story’ mode of OoL research (e.g. “*Here’s a string of connected, extremely detailed arguments for why X, Y, and Z all played a role in the OoL, and it MUST have happened this way…*”)



# Personal observations

The ‘story’ approach isolates research groups.

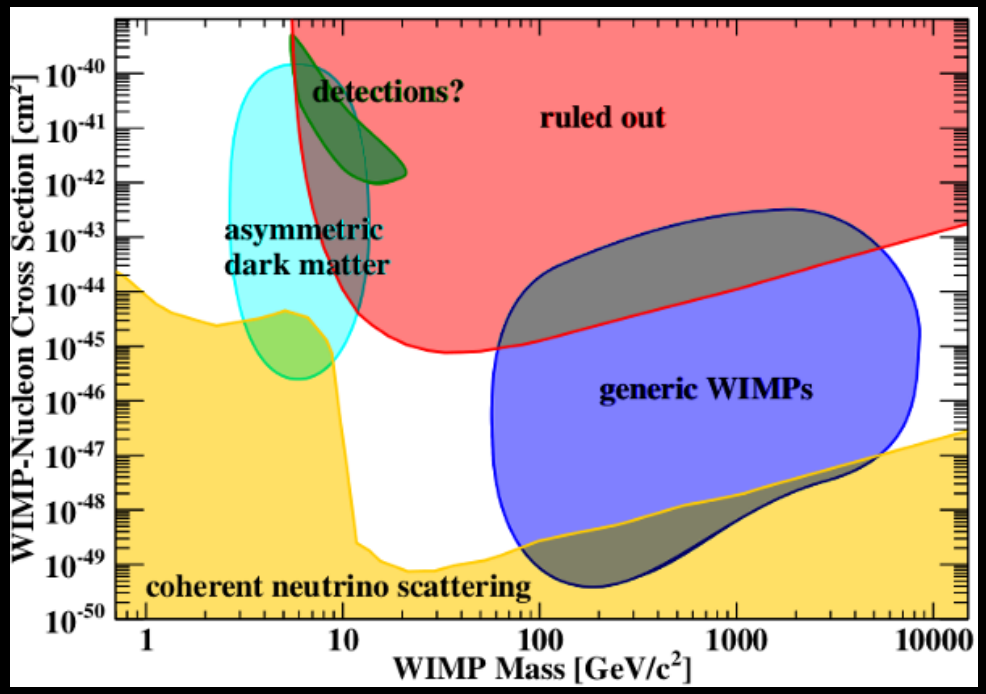
This approach also complicates testability, and the development of a proper theoretical basis for OoL.

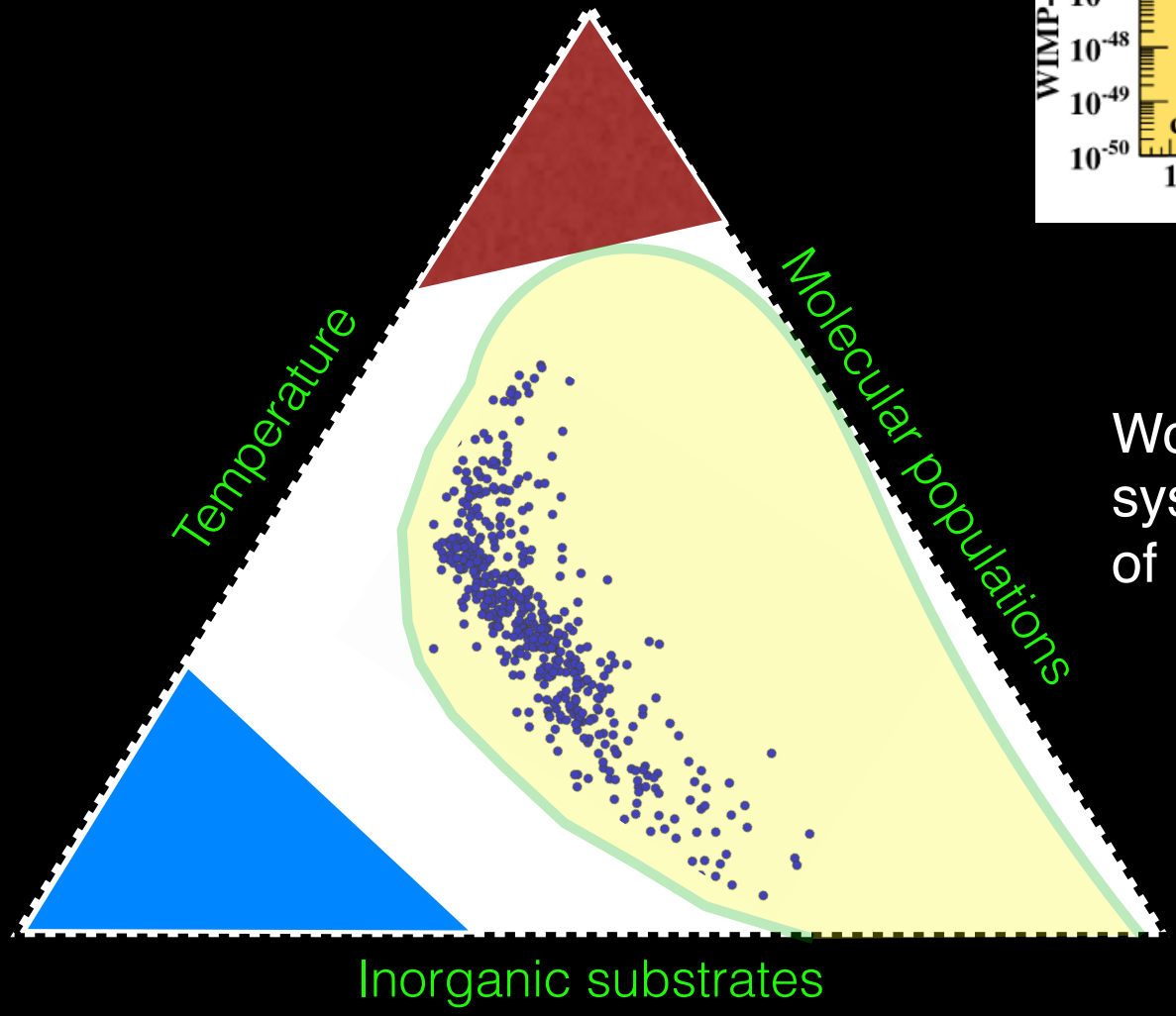
At some level it is tantamount to stating that OoL is ‘simply too complicated’ for standard hypothesis elimination. That is problematic.

**Bringing ALife and OoL together, performing new experiments (e.g. long-term, or machine-mediated), and organizing competitive challenges all seem like ways to disrupt OoL research positively…**

# Personal observations

Can OoL research exploit methodologies from other fields, like physics?




Work as a community to systematically eliminate parts of 'parameter space' for OoL?

**Astrobiology could play a critical role?**