

# Open-endedness and Novelty in Evolution

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## Workshop on Open-ended

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# Result

## Defining and Simulating Open-Ended Novelty: Requirements, Guidelines, and Challenges

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### Abstract

The open-endedness of a system is often defined as a continual production of novelty. Here we pin down this concept more fully by defining several classes of novelty and innovation that a system may exhibit. This leads to a definition of *levels of structure* in a systems model. From there, we define an architecture suitable for building simulations of open-ended novelty-generating systems. We also state some challenges for the community.

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# What is OEE?

- OEE = Continuous creation of novelty
- OEE = Continuous increase in complexity
  
- Effective OEE = Inexhaustible creation of novelty
- Effective OEE = Inexhaustible potential increase in complexity
  
- OEE = Boundless diversity



# Novelty

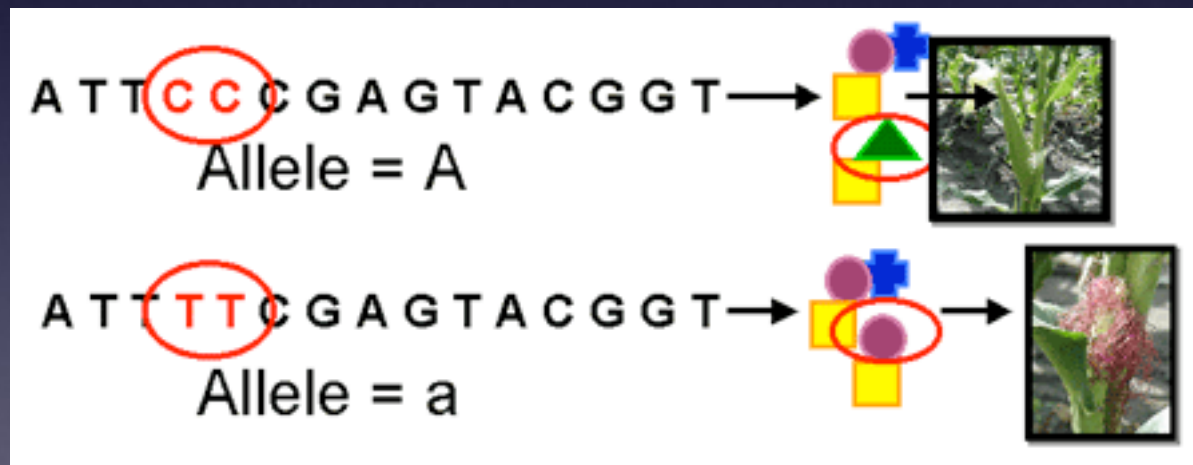
- Specific type of change in and of a model
- Meta-model to describe model
- Model: Systems with entities, organized into levels
- Meta-model: Describes the level structure
- Change and time

# Types of Novelty

- Type 0 Novelty: *Variation* = Novelty within a model
- Type 1 Novelty: *Innovation* = Novelty that changes the model
  - 1a *Dimensional Innovation* = Change in size/structure of space
  - 1b *Type Innovation* = New types of entities
- Type 2 Novelty: *Emergence* = Changes the meta-model
  - 2a *Transition* = Addition of a new level
  - 2b *Major Transition* = Entities at new level are units of reproduction

# Example: Type 0 - Variation Novelty within a model

- Changing a gene to a different allele

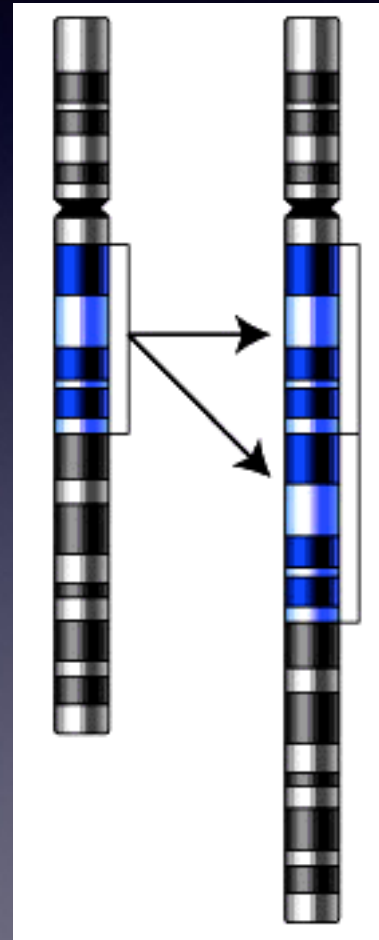


Plant & Soil Sciences eLibrary, 2015

# Example: Type Ia - Dimensional Innovation

## Novelty that changes the model

- Gene duplication



Wikipedia



# Example: Type 2a - Transition Novelty that changes the meta-model

- Ecosystem formation



Wikipedia: Inside of Biosphere 2

# Novelty & Complexity

- Combinatorial spaces of a given dimension are exhaustible
- The Universe is a combinatorial space though a large one ( $10^{40}$  time units x  $10^{80}$  particles =  $10^{120}$ )
- Bit strings of length 400 bits are of comparable size

# Is Novelty Sufficient for OEE?

“No” at any level of complexity:

- The number of novelties goes to zero as search time goes to infinity

“Yes” if complexity can grow:

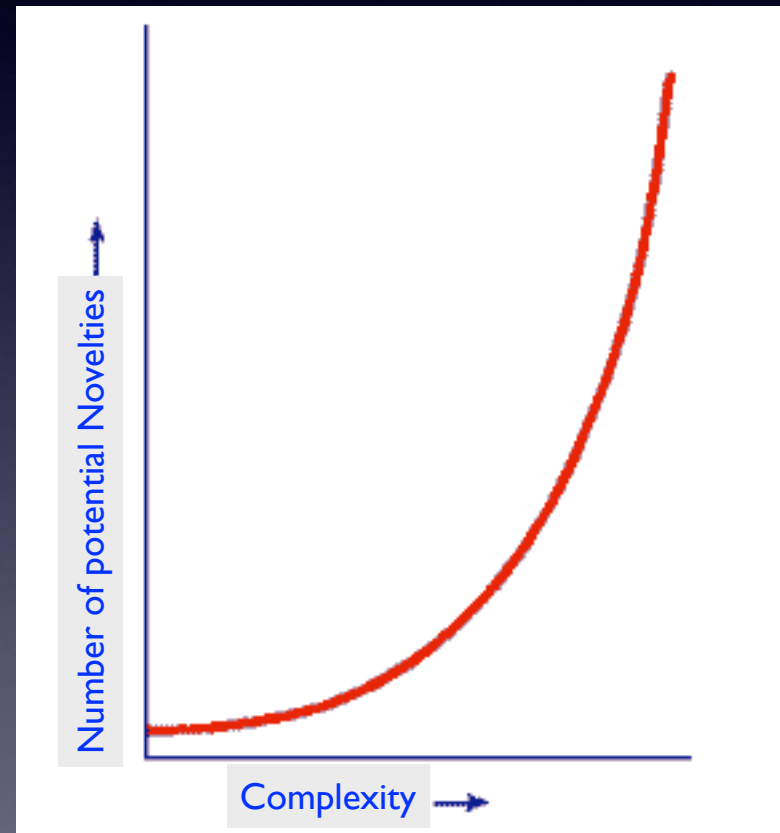
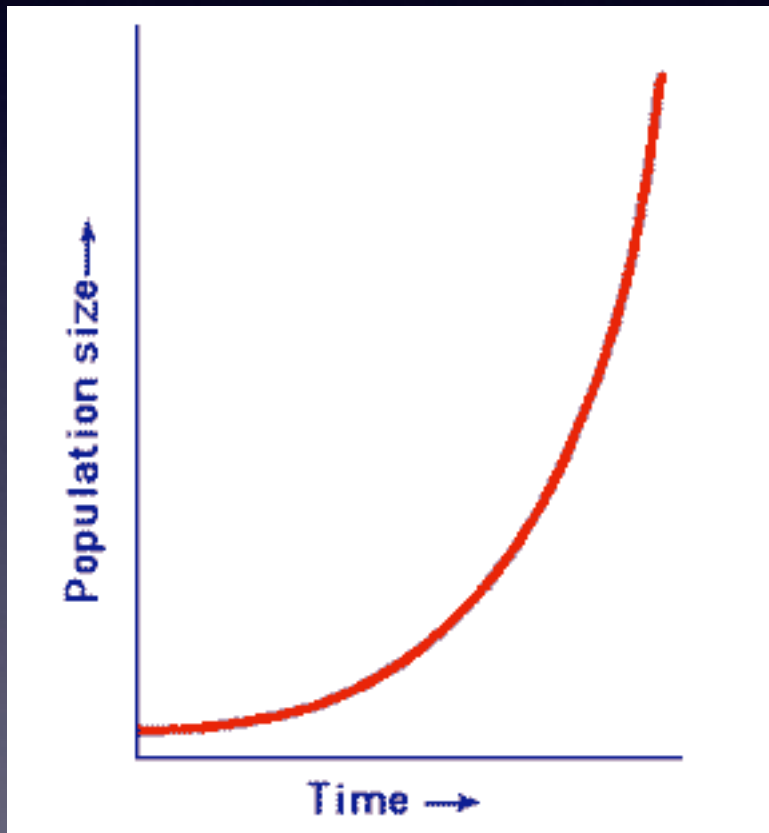
- Number of realizations (and therefore of novelties) grows exponentially with complexity

# What is the driving force for OEE?

## Natural Selection

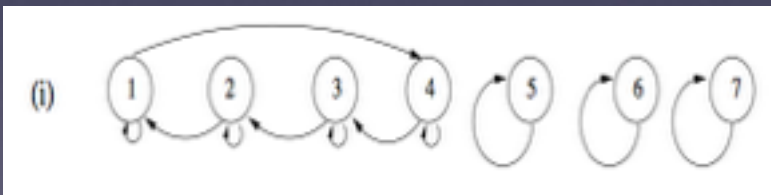
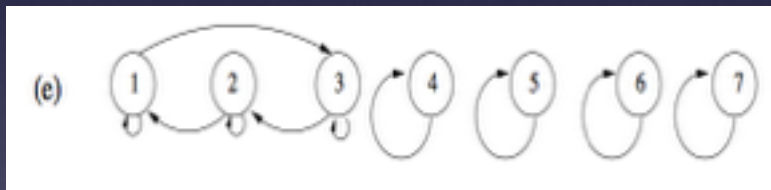
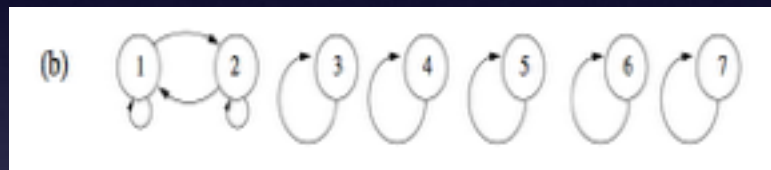
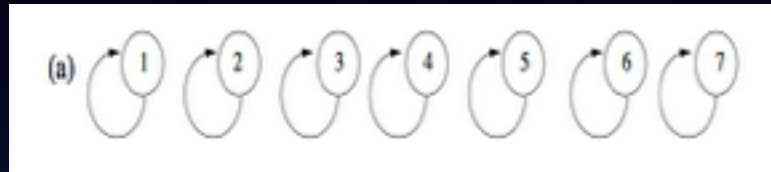
- Amplification (exponential growth of population with time)
- Competition due to resource constraints

# Time & Complexity



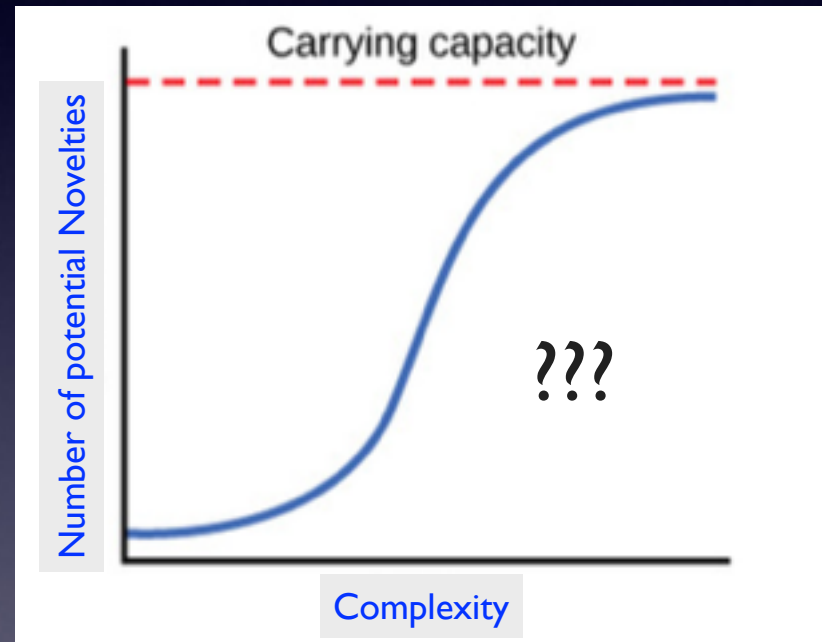
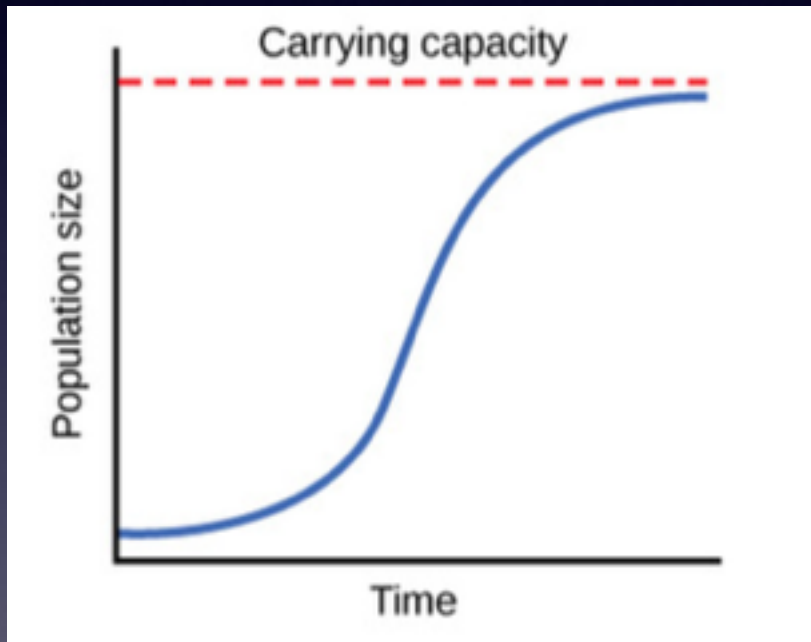


# More complex systems seem to evolve faster!



- Simple model of competing (autocatalytic) entities
- Competition settles faster the more cooperation among entities
- Speed pushes for higher complexity

# Is there a limit?



# Evolution in Action

Change of perspective:

- From individuals that compete against each other for food
- to points in possibility space (eg. novelties) that compete for occupation by individuals
- Required is a sufficient number of individuals to compete for these novelties
- Resource limitation (matter in the universe) leads to limit on the number of levels that can be populated
- Search will be path-based, rather than volume-based in these possibility spaces
- Therefore the relevance of “the adjacent possible”
- Note: Novelty search is volume-based and not effective

# References

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# Questions?