Diversity in Biological and Computational Populations

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Topic: This review will synthesize research on diversity within and across evolving populations. Our focus includes diversity at the genotypic, phenotypic, behavioral, and ecosystem levels. While we will touch on the implications of diversity for long-term population dynamics (particularly evolutionary potential), the emphasis of this review will be on factors that promote the generation and maintenance of diversity (i.e. we will not, for instance, attempt to rehash the entire field of biodiversity and ecosystem functioning).

Fields:

- *Evolutionary Biology* - As diversity within a population is critical for evolution to occur, evolutionary biologists have been particularly concerned with genotypic and phenotypic diversity within a given population or species. Population geneticists in particular have done excellent work towards quantifying changes in gene and trait level diversity in biological populations.
- *Ecology* - The question of why we see so much biodiversity as we do is central to ecology. Ecologists tend to be more concerned with interspecific diversity
- *Evolutionary Computation* - Premature loss of diversity is the primary obstacle to the success of evolutionary algorithms. As such, researchers in this field have spent a great deal of effort cataloging the dynamics that promote and inhibit diversity.
- *Artificial Life* - Heavily influenced by the above fields, research on diversity in artificial life pulls from all of these ideas. In particular, this body of research is capable of addressing theoretical questions about diversity that cannot be tested in a biological system and that most people doing evolutionary computation don’t care about.

Why this review is important:

While research on evolutionary computation was originally inspired by evolutionary biology research, few biologists think to turn to evolutionary computation research for answers to theoretical questions. Since the goal of pure evolutionary computation research isn’t to learn more about biology, even when evolutionary computation research happens to yield a result that is applicable to biological evolution, it is rarely presented as such. This review will do the extra layer of work required to make it clear where results from evolutionary computation have biological implications.

While evolutionary biologists and ecologists talk to each other a lot more than evolutionary biologists and computer scientists, there has still been a historical disconnect between the fields. Ecologists do an incredible amount of research on diversity, but often don't tie it back to evolutionary mechanisms. Evolutionary biologists study diversity within a population up until the point of speciation, but rarely consider what happens next. Recent advances, such as the entire subfield of eco-evolutionary dynamics, have begun to remedy this disconnect, but there is a lot of work left to do. This review will provide an accessible explanation of our current state of understanding of the evolution of diversity, and highlight areas where further research is necessary.

Glossary:

- *Niche*: In evolutionary computation, a niche is an area of the fitness landscape that is being accounted for by a single species, whereas in biology it is the range of environmental properties that a species needs to survive. There are similar practical implications, in the both niches are regions within which competitive exclusion is expected to occur, but they are mechanistically very different.
- *Functional Diversity*: In biology, this term refers to the variety of traits thought to be relevant to ecosystem functioning that are present in a population.
- *Solution*: A member of a population in evolutionary computation. *Agent* is sometimes used instead if population members are able to make decisions.

Outline:

- **Introduction:**
    - Why it's useful for biologists to look at CS and computer scientists to look at biology. High-level summary of field.
    - Perhaps a bit of discussion on metrics and types of diversity
    - Start by talking about biology - appeal to evolutionary biologists
    - compare and contrast
    - talk about range of scales in biology, then talk about CS
    - driving questions behind fields
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- **Diversity in Biology:**
    - Mostly care about origins, drivers, and effects of diversity (with occasional attention paid to maintenance of diversity)
    - Also in general much more of a focus on the practical implications of diversity.
    - Evolutionary biology

            - Intraspecies diversity -> maintaining heterozygosity important to adaptability
            - Need to do more background research here
    - Ecology
        - Interspecies diversity
        - Diversity in interaction types (also touched on in ALife by Luis' paper)
        - Metrics of diversity, challenges in measuring, etc.
        - Functional diversity
        - Research on importance of biodiversity -> biodiversity and ecosystem functioning
- **Diversity in CS:**
    - Evolutionary computation:
        - Major focus on maintaining diversity.
        - Discuss ways in which people have tried to maintain diversity.
            - categories from concept map
    - Artificial Life:
        - Still more of a focus on maintaining diversity
        - Also study origins, drivers, and effects of diversity
            - Summarize research
                - Avida (probably the majority of this section)
                - Urdar
                - Other systems
- **Comparison:**
    - A lot of terms get used fairly similarly across fields:
        - Niches
        - Speciation (mechanism for this gets fudged in EC, but end result roughly the same)
        - Island models (EC/50's ecology)/metacommunities (modern ecology)
        - Spatial population structure
    - Some have more complicated relationships… to what extent can these inform each other?
        - Functional diversity
        - Genotypic vs. phenotypic vs. behavioral diveristy
    - How do different diversity metrics fair in different contexts?
        - Richness
        - Shanon Diveristy
        - Simpson's Index?

- **Conclusion:**
    - Summarize important takeaways for both fields
        - Has EC done anything that biologists haven't? Have they learned anything that it would be useful for biologists to know?
        - Alife obviously does things relevant to all fields.
        - Biology obviously has historically been important to both other fields - are there more recent discoveries that computer scientists should be paying attention to?
        - There should be better mechanisms for communication between fields.
        - open questions interesting to both fields