During its early history, visions for the near future of evolutionary computation were in part characterized by grandiosely optimistic expectations (cite: 90s Kozaaaaaa), many of which have yet to be fully realized (cite: that one really savage review paper). Among other explanations for this incongruity, one possible contributing factor was 20th century confidence in the modern synthesis of evolutionary biology, which held the principles of Mendelian inheritance and Darwinian selection largely sufficient to explain natural life — and thus perhaps also sufficient to achieve lofty goals in EC.

Instead, evolutionary computation came face-to-face with extensive challenges in convergence to local optima. In response, the field has devoted significant attention to overcoming these challenges through

a. dynamic selection strategies facilitating exploration and maintenance of useful diversity, and
b. biased representations and variation operators facilitating generation of useful diversity.

In parallel, evolutionary biology has also run up against major explanatory limitations of the modern synthesis — prompting calls for movement towards an extended evolutionary synthesis. Key areas of interest include,

a. dynamic eco-evolutionary feedbacks facilitating niche construction and maintenance of ecological diversity (eco-evo), and
b. physiological constraints and developmental processing shaping the generation of phenotypic variation (evo-devo).

Indeed, it is these correspondences that most strongly motivate our tenet that theory from biology merits greater consideration in evolutionary computation (and vice versa). To begin, we will briefly review classical topics falling under the purview of the modern synthesis, including

- fitness, selection, (*Jose/Phil*)
- fitness landscapes, (*Bhaskar*)
- and population genetics. (*Alex/Phil)*

Then, we will shift to cover topics around exploration and diversity maintenance, including

- biodiversity metrics, *(Shakiba)*
- ecological feedback, *(Emily)*
- coevolution, *(Anya)*
- open-endedness, *(some existing text from Vinnie)*
- and adaptive momentum. *(Vinnie)*

Finally, we will conclude with topics involving representation and variation, including

- plasticity, *(Anselmo/Nick)*
- recombination, *(Anselmo/Nick)*
- and evolvability. *(Bhaskar)*

In our presentation, attention will be devoted to highlighting biological perspectives and corresponding theory potentially relevant to EC, although discussion will also highlight corresponding elements in EC literature — with special emphasis to areas where theory from biology has been directly translated to EC.

Cites: Extended Evolutionary Synthesis

Section 1: Fundamental Concepts

- ***Subsection: Fitness*** (*Jose/Phil*)
  - e.g., fitness as an outcome rather than a "cause"
  - Biological and EC fitness definitions
  - How does this inspire EC algorithms?
  - 2 framings of this:
    i. Evolution as a means to evovle solutions for a given problem (e.g. program synthesis)
    ii. Evolution setups as a means to evolution/biology itself
  - How is this captured within EC?
- ***Subsection: Fitness Landscapes*** (*Bhaskar*)
  - may also mention genotype-phenotype map
  - See "unclaimed refs RE local optima/evolvability/genotype-phenotype maps" in issue 9
- ***Subsection: Phenotypic Plasticity*** (*Anselmo/Nick*)
  - incl lifetime learning, epigenetic memory?
- ***Subsection: Ecology and Coevolution*** (*Luis/Emily/Anya*)
- ***Subsection: Population Genetics*** (*Alex*)
  - sweeps and time to fixation
  - bottlenecking and effective population size

Theme: Existing Connections

Sections:

- **2. Theory Application: Selection Schemes** *(Jose)*
  - A suite of diagnostic metrics for characterizing selection schemes
  - What can handcrafted search spaces tell us about selection scheme mechanism?
  - How are they applicable to real-world scenerios?
- **3. Theory Application: Diversity Measures** (*Shakiba*)
  - What Can Phylogenetic Metrics Tell Us About Useful Diversity in Genetic Algorithms
  - Untangling Phylogenetic Diversity's Role in Evolutionary Computation
  - perhaps useful to give a general overview of "biodiversity" theory/measures?
  - correspondences/contrast to typical EC measures (e.g., https://gpbib.pmacs.upenn.edu/gp-html/Nguyen_2006_ASPGP.html)?
- **4. Theory Application: Diversity Maintenance** *(Emily)*
  - Applying Ecological Principles to Genetic Programming
  - Ecological Theory Provides Insights about Evolutionary Computation
  - Reachability Analysis for Lexicase Selection via Community Assembly Graphs
  - comparison/contrast with e.g., https://doi.org/10.1145/3638530.3648430, https://arxiv.org/pdf/1801.10087?

Theme: Promising Opportunities

Sections:

- **5. Biological Perspectives on Variation Operators** *(Nick/Anselmo)*
  - e.g., recombination asymmetries (modularity?), horizontal gene transfer, etc.
  - correspondences/contrasts with schemata/building block theory?
- **6. Biological Perspectives on Local Optima** *(Vinnie)*
  - could also frame title as "premature convergence" rather than "local optima"
  - might connect adaptive momentum to fitness peak escape, exploration vs. exploitation (eg super-explorers)?
  - see "unclaimed refs RE local optima/evolvability/genotype-phenotype maps" in issue 9
- **7. Biological Perspective on Population Structure** *(Oana)*
  - draw connections/contrasts with EC theory around "island model" populations?(e.g., "46.3 On the Spread of Information in Parallel EAs" in https://doi.org/10.1007/978-3-662-43505-2_46)
- **8. Biological Perspectives on Coevolution** *(Anya)*
  - might compare/contrast with "cooperative/competitive" coevolution" framing in EC
  - might reference early work by Richard Watson (e.g., https://www.cs.brandeis.edu/~richardw/symbiosis/)
- **9. Biological Perspectives on Evolvability** *(Bhaskar)*
  - might compare/contrast dynamic "evolution of evolvability" perspective with more static genotype-phenotype map design framing?

    - see “unclaimed refs RE local optima/evolvability/genotype-phenotype maps” in issue 9
- **10. Evolutionary Computation Insights on Evolvability** *(Matthew)*
    - learning theory/generalization (e.g., https://doi.org/10.1371/journal.pcbi.1005358 https://doi.org/10.1016/j.tree.2015.11.009)