Plasticity and Evolvability in a Gene Regulatory Network Model

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Introduction

Environment and Development

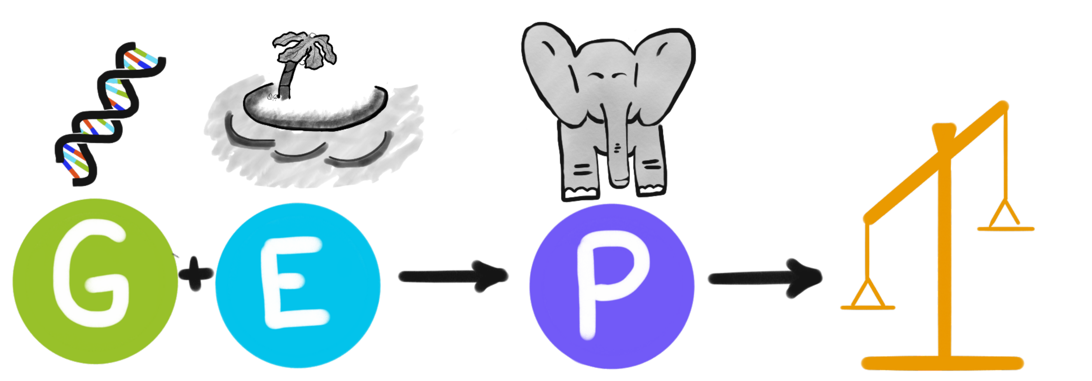

Figure 1: Genetic and environmental factors both influence the phenotype, which, in turn, determines fitness.

Direct Plasticity [1]

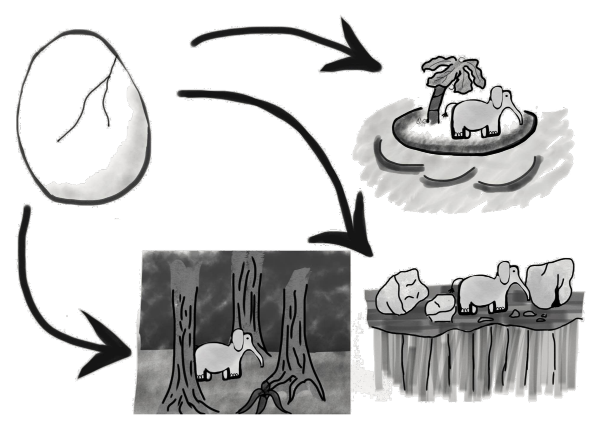

Figure 2: In this cartoon, phenotypic form is stable under environmental perturbation.

Indirect Plasticity [1]

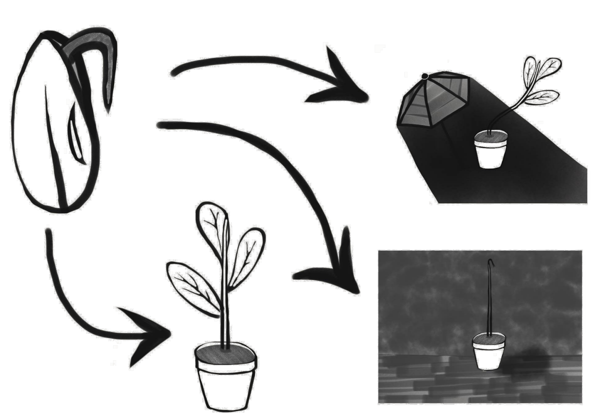

Figure 3: In this cartoon, alternate phenotypes are expressed based on environmental signals.

Gene Regulatory Network Model

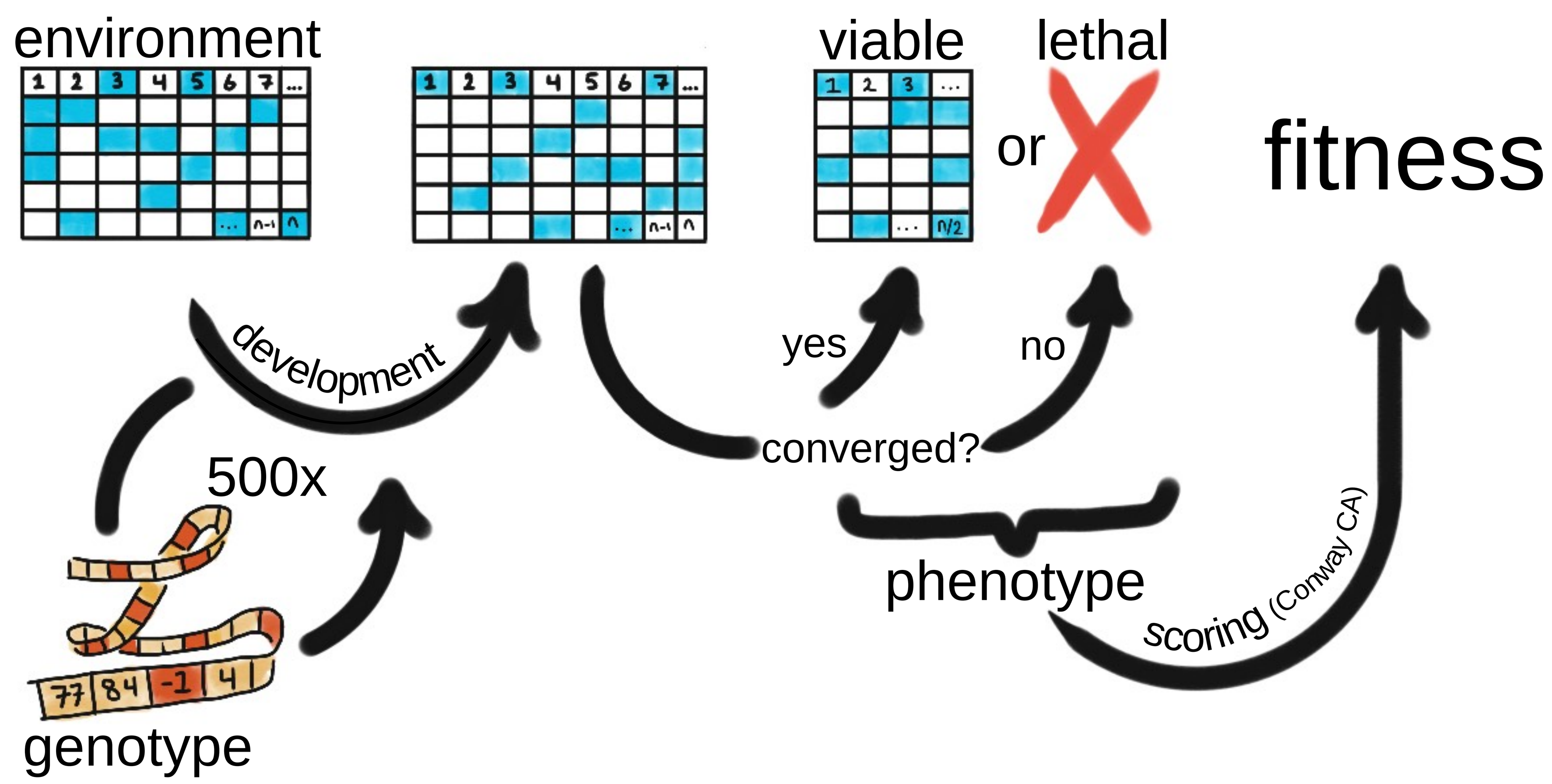

Figure 4: A cartoon overview of the development and assessment processes of the expanded model, based loosely on [2].

A genome consists of a fixed-length set of if-then rules. Each rule has three components: the index of a chemical antecedent, the index of a chemical patient, and description of the action of the antecedent on the patient. This relationship may be inhibitory, excitatory, or neutral. To generate the phenotype, the genomic rules are applied 500 times to an initial state $S(0)$, representing the environment, yielding a final state $S(500)$. A phenotype is deemed inviable if $S(500) \neq S(501)$. To enable sophisticated regulatory interactions in the network, viable phenotypes are defined as a subset of the final set of chemical states $S(500)$ so that a portion of chemical products are hidden from direct exposure in the phenotype. Phenotypic fitness is assessed using a metric based on Conway's cellular automata.

Experimental Treatments

Control

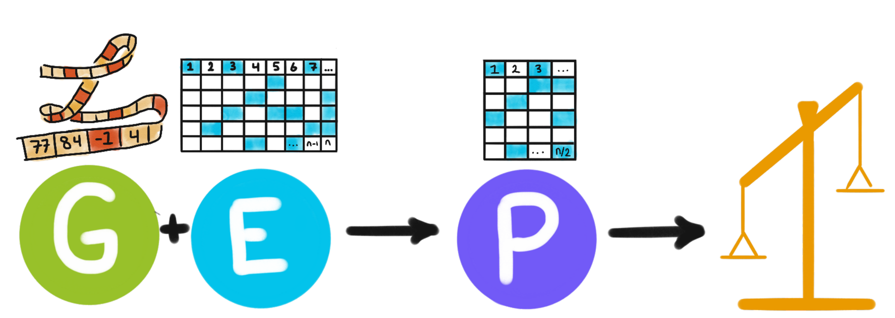

Figure 5: In the control scheme, a static environment is used for each evaluation of a genotype.

Direct Plasticity

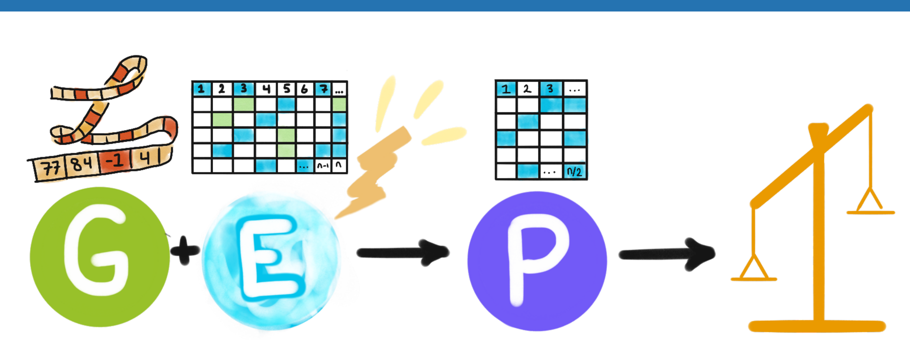

Figure 6: In the direct plasticity scheme, a subset of the initial environmental states are randomized for each evaluation of a genotype.

Indirect Plasticity

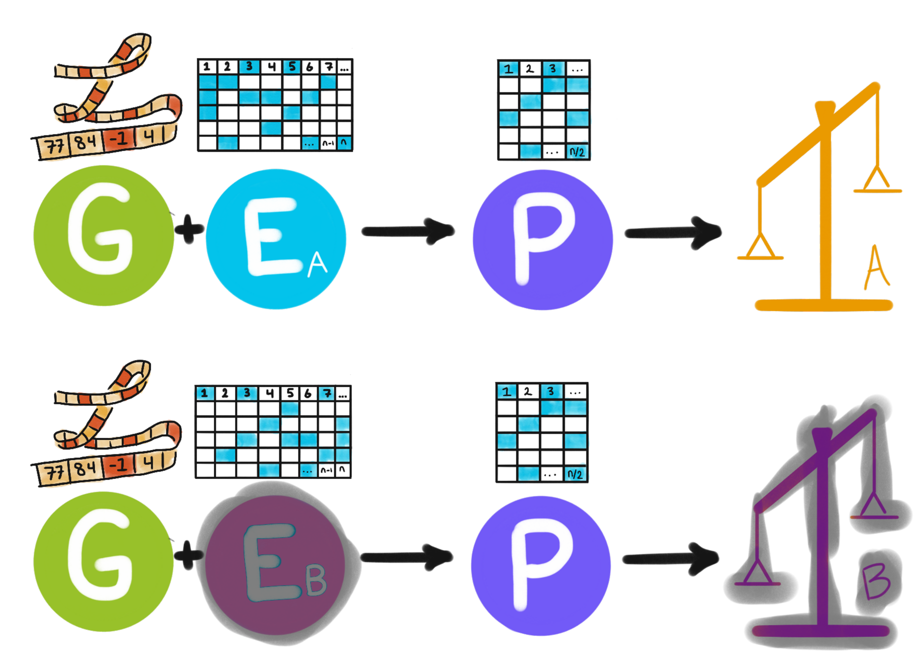

Figure 7: In the indirect plasticity scheme, a pair of alternate environments signal which of two evaluation criteria is employed.

Preliminary Results

Direct Plasticity

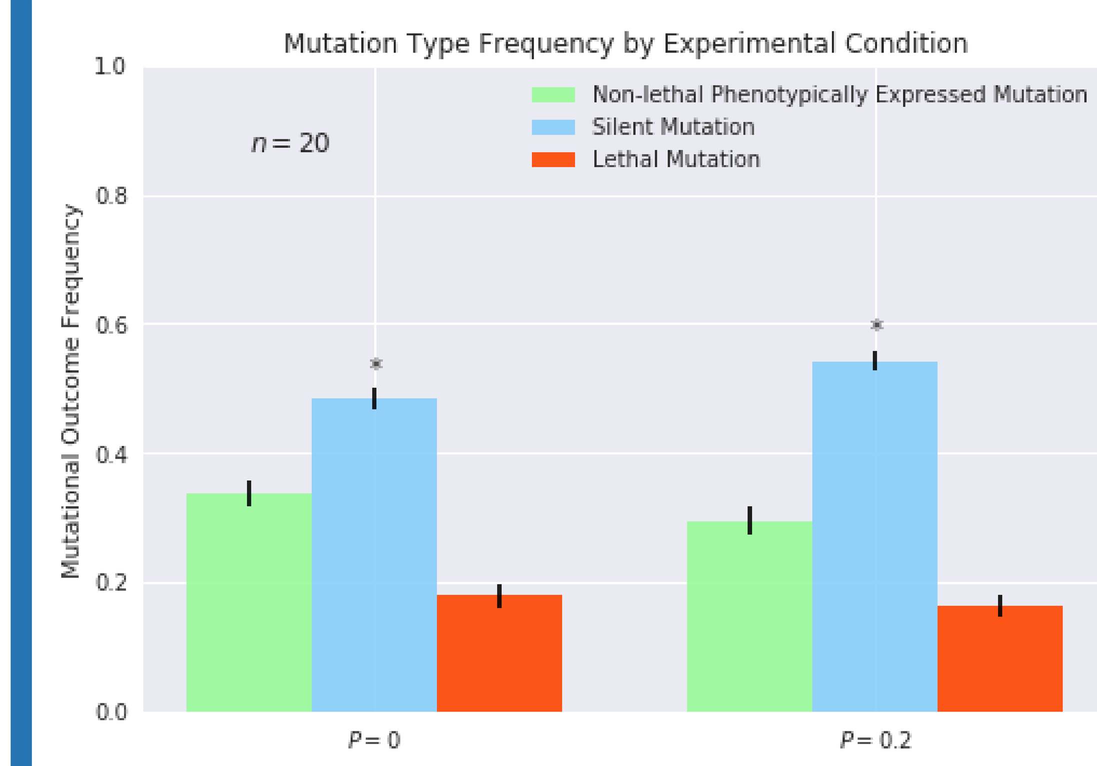

Figure 8: Champions evolved under a regime with initial state perturbation experience a higher rate of silent mutational outcomes.

Indirect Plasticity

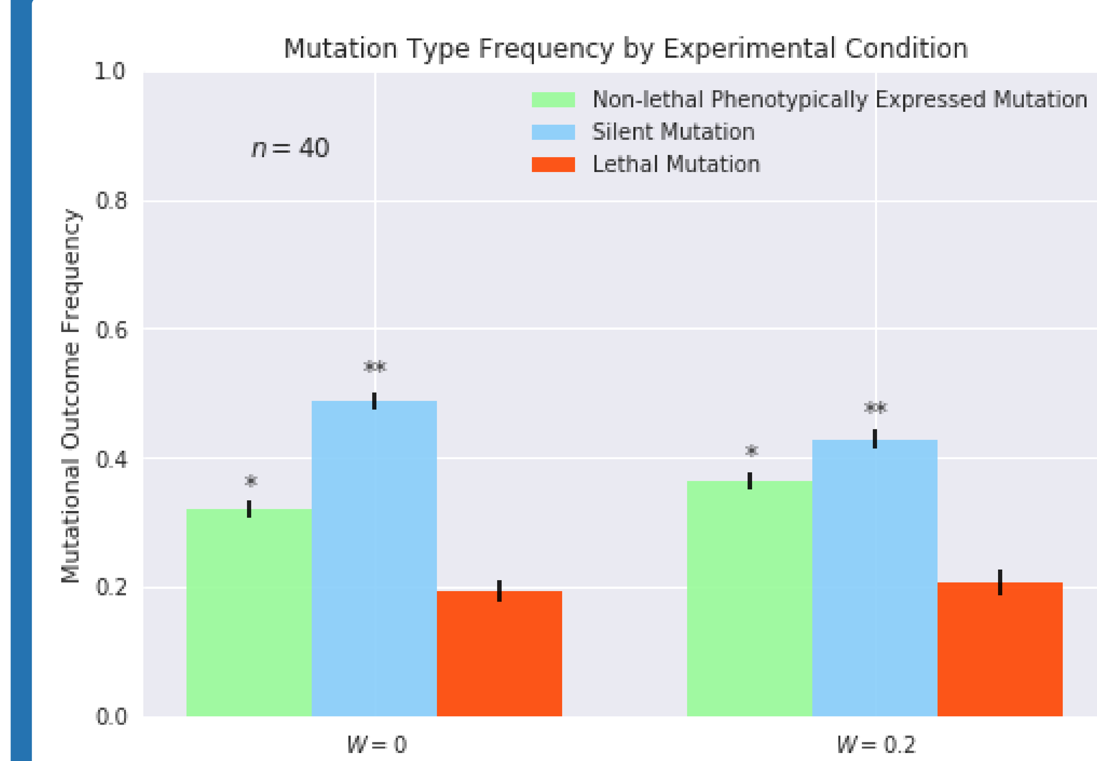

Figure 9: Champions evolved with both primary and secondary condition/objective pairs experience a lower rate of silent mutational outcomes and a higher rate of nonlethal phenotypically observed mutational outcomes.

Next Steps

- investigate structural mechanism for observed differences in response to mutation
  - assess phenotypic outcomes of combined pairs of mutations
  - assess skeletonized genotypes as graphs
- investigate capacity of individuals evolved under different regimes to switch objectives
- replicate results with more sophisticated model

References

[1] G. Fusco and A. Minelli.
Phenotypic plasticity in development and evolution: facts and concepts.
Philosophical Transactions of The Royal Society, 365:547–556, 2010.

[2] B. Wilder and K. Stanley.
Reconciling explanations for the evolution of evolvability.
Adaptive Behavior, 23(3):171–179, 2015.

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