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SP/10 Evolution

How Various Mutation Rates and Environments Interact to Affect the Fitness of an Organism

The intent of this research and experiment is to investigate how various mutation rates and environments interact to affect the fitness of an organism. Mutations create variation, which is the essential fuel for evolution to occur, although, most mutations that occur are usually neutral or deleterious. Environmental stresses amplify these negative mutations to be harmful to an organism's success in its environment and its fitness. A study in 2003 challenged this notion and suggests that there are stresses with the opposite influence, under which helps an organism become more tolerant to mutations. The study measured growth rates of Escherichia coli mutants in an assorted set of environmental stresses. The results identified that environmental conditions are a factor in altering effects of mutations and can alleviate the effect of deleterious mutations.[1] A different study questioned the effect of environmental stresses on fitness in cultures of Chlamydomonas. The stresses included a range of temperatures, osmotic stress, low pH, starvation and toxic stress. Results found that, "there was a strong tendency for stressed cultures to have lower mean fitness and greater standardized variance in fitness."[2] Another experiment found that interactions between multiple compensatory mutations could transform deleterious mutations into neutral or beneficial ones. This then causes fitness reversals, changing from negative to positive.[3] These studies have all proven that when mutations and another factor i.e. environmental stresses or a compensatory mutation, are concurrently influencing an organism, the fitness rate can be affected. My

hypothesis is that the higher mutation rates placed in moderately harder environments will have higher fitness.

My experiment was carried out using the Avida- Ed simulator program to observe the evolution of self-replicating, autonomous digital organisms. Each test used the same ancestral organism, which was then manipulated to have various mutation rates and inhabit various Avida pre-programmed environments ranging from 'easy' to 'brutal.' The mutation rates chosen to study were a range between 0-2%, previously tested to be the optimal mutation rate for fitness. The intervals of mutation rates were .4%,.8%,1.4%,1.8% to get an average range. Each was tested in 'easy', 'moderate', 'hard', 'very hard' and 'brutal' environments. These environments contain distinctive resources available in the form of Avida invented sugars. Easy had 'notose' and 'nanose'. Moderate had 'andose' and 'ornose'. Hard had 'orose' and 'antose'. Very hard had 'norose' and 'xorose'. And Brutal had only 'equose'. All mutation percentages were placed in each of these separate environmental conditions and run for 500 time updates. Each experiment was performed 3 separate times to obtain average results.

The results found showed variation in most all cases. The 'easy' environment always yielded the highest fitness in all mutation percentages. The rate was always higher than an organism at 0% mutation. As charts 2a, 3a and 4a show, the rate was not always consistent in its progression over time. Chart 3a, illustrating 1.4% mutation, shows a rise and decline resulting in a lower fitness (.33) then where it peaked (.37). The 'moderate' environment produced the second highest fitness in all mutation percentages, generally more beneficial than having 0% mutation, with the highest (.29) in .8% mutation (Chart 2b). It then progressively declined with the higher mutation rates

dropping down to .24 (Chart 3b, 4b). The 'hard' environment was at its highest (.28) in the .8% mutation setting and showed large range of variation between the 3 trials. (Chart 2c). In every environment the general trend over time (x axis) showed many rises and falls in fitness level. The 'very hard' environment tests produced a consistent fitness rate (.24) with every mutation percentage (Chart 1d, 2d, 3d and 4d). In 3 out of 4 cases it was always higher than the 'hard' environment (Chart 5a, 5c,and 5d). The general trend in all the trials showed a stable progression over time. Finally the 'brutal' environment had the lowest fitness in every mutation percentage. The number was generally consistent in every trial (.23) and the progression over time was a steady decline. In some cases the fitness level averaged to be the same what the 'hard' environment produced.

The two extremes of the environments generally produced predictable results. An organism living in an easy environment will most likely have the highest and most advantageous traits. The hardest environment generally yields the lowest traits. The main discovery is related to the mutation rate. The results show that a higher mutation level generally yields higher fitness level. In the 'brutal' environment the level of mutation seemingly has no effect, it produces no greater or lesser results. This is also applicable to the 'very hard' environment, which had a consistent fitness level (.24) with every mutation percentage. In the trails testing .4% 1.4% and 1.8% mutations there was a greater advantage over the 'hard' environment, meaning that it was generally advantageous to be in the more difficult environment. The 'hard' and 'moderate' environments resulted in the most variation in which both environment and mutation percentage had different effects. Both of these environments did the best in the .8% mutation trials. In different percentages they did slightly or even dramatically lower

(Charts 4b and 4c) compared to others. In conclusion, different combinations yield different results for the mid range variables. In the hardest environments it seems it is more advantageous to have 0% mutation rate than any. 0% gives a .25 result, higher than the tested percentages. In the easier environments even a slight percentage of mutations is more advantageous than none. Further investigation can be made to answer questions relating to mutation percentages. At what percentage, if there is any, is it beneficial to have mutations in a brutal environment? Or at what percentage is it detrimental to have mutations in an easy environment? These questions will further resolve the relationship and interaction between mutation rate and environment.

Bibliography

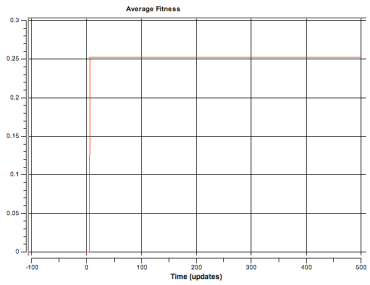
1. Kishony R, Leibler S. "Environmental stresses can Alleviate the Average Deleterious Effect of Mutations." Laboratory of Living Matter, Rockefeller University, PubMed.gov 2003 May 29 < http://www.ncbi.nlm.nih.gov/pubmed/12775217>

2. S. Goho and G. Bell, "Mild Environmental Stress Elicits Mutations Affecting Fitness in Chlamydomonas." Biology Department, McGill University, Proceedings of the Royal Society, 2000 January 22 < http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1690507/> full text

3. Matthew C Cowperthwaite, J. J Bull, and Lauren Ancel Meyers, "From Bad to Good: Fitness Reversals and the Ascent of Deleterious Mutations" The Institute for Cellular and Molecular Biology, The University of Texas at Austin, PLoS Computational Biology 2006 October 20 < http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1617134/>

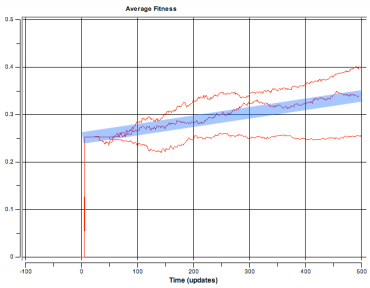
Appendix

0% Mutation Rate in multiple environments

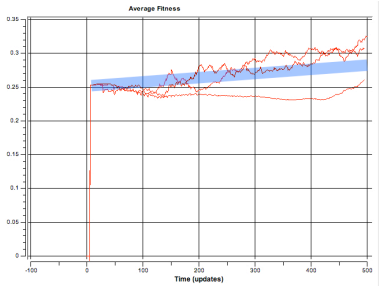


1. Easy, Moderate, Hard, Very Hard, Brutal- Same result

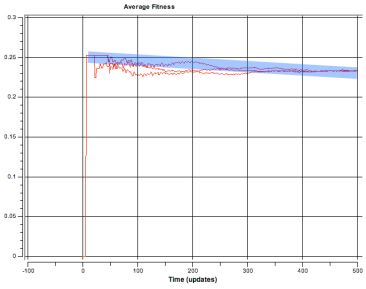
.4% Mutation Rate in multiple environments



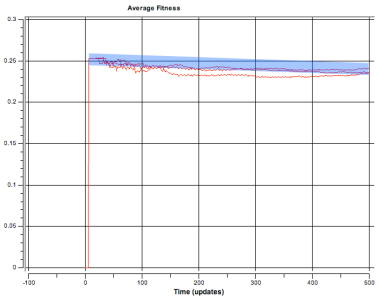
1a. Easy



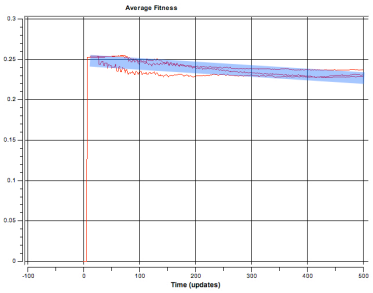
1b. Moderate



1c. Hard

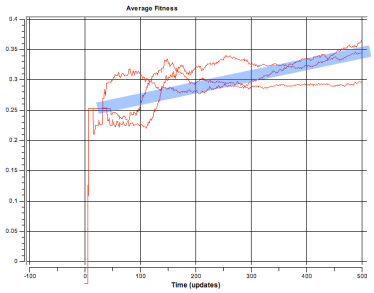


1d. Very Hard

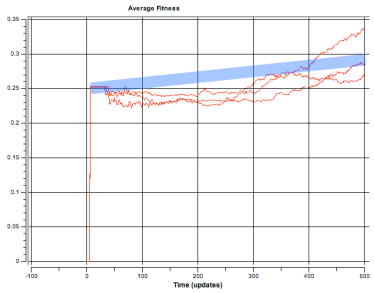


1e. Brutal

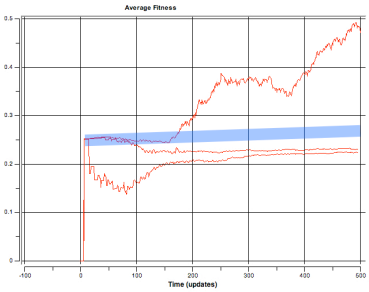
.8% Mutation Rate in multiple environments



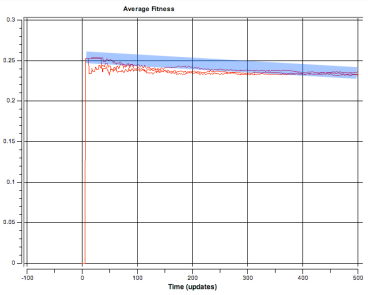
2a. Easy



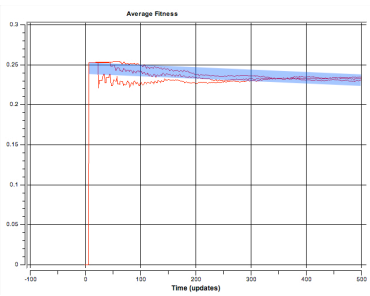
2b. Moderate



2c. Hard

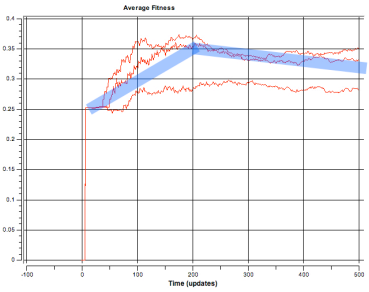


2d. Very Hard

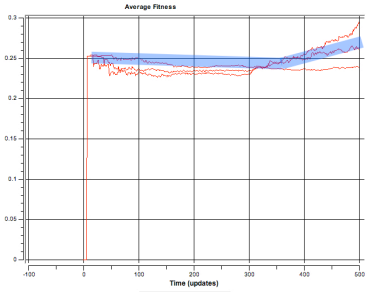


2e. Brutal

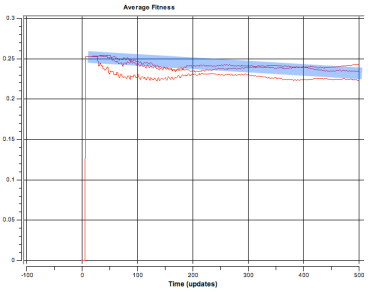
1.4% Mutation Rate in multiple environments



3a. Easy



3b. Moderate



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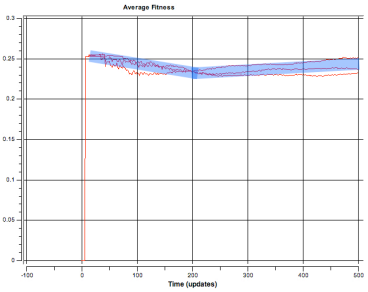

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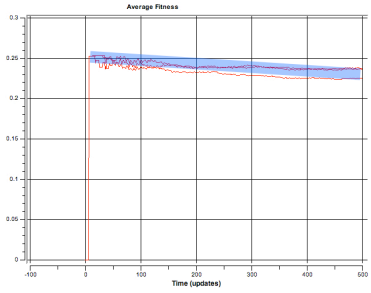
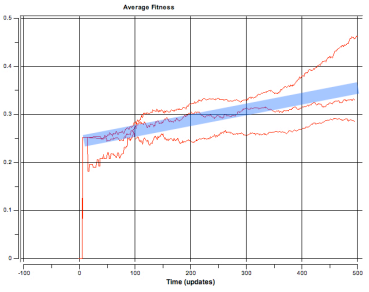
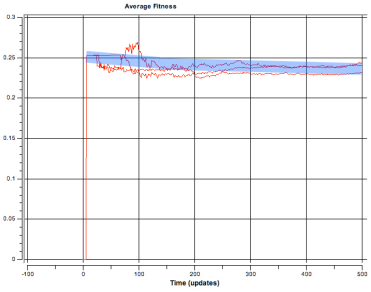


2e. Brutal

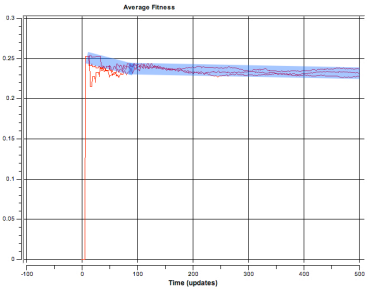
1.8% Mutation Rate in multiple environments



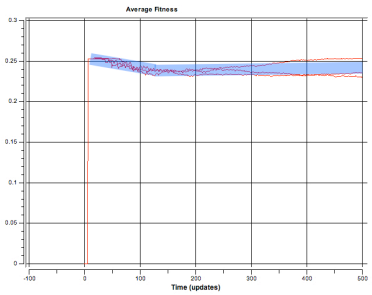
4a. Easy



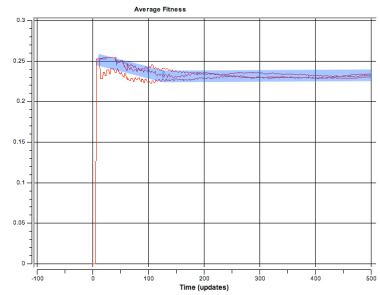
4b. Moderate



4c. Hard

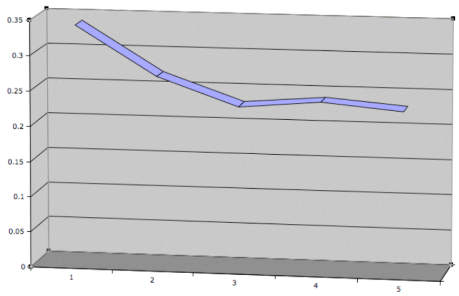


4d. Very Hard

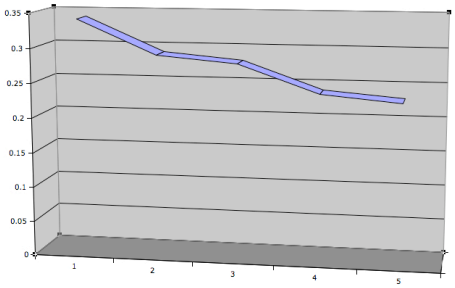


4e. Brutal

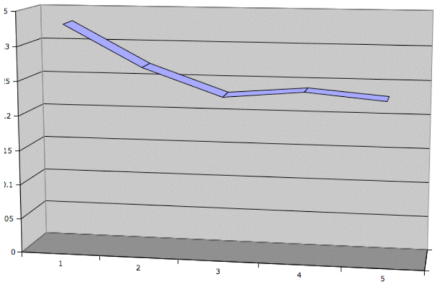
x axis- 1-Easy 2-Moderate 3-Hard 4-Very Hard 5-Brutal
y axis- average fitness



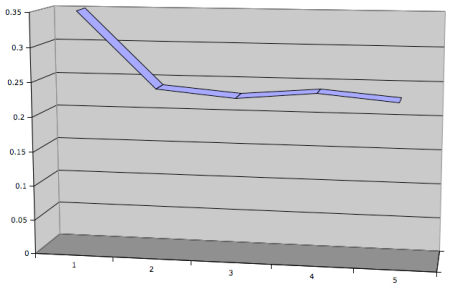
5a. .4% Mutation



5b. .8% Mutation



5c. 1.4% Mutation



5d. 1.8% Mutation