J. McHale Ourand
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Term Project Proposal

Term Project Proposal: Natural Selection

Natural selection has always been seen as a slow process. It takes generation after generations to separate the organisms that variations succeed in their environment from those that don't. But recently, gradual natural change has spiraled out of control by the actions of humans. Climate change has just started to ramp up and with the current trend the rate of environmental destruction will continue to get worse before it gets better. As these changes to the physical environment occur much more rapidly, it forces organisms to confront and adapt to new challenges in a rate we haven't seen before. We have no surefire way to know how organisms that are affected will adapt or even if they will continue surviving but we can see how these changes in the environment affects their populations by applying logic, experimental data, and the mechanisms of natural selection to help project what behaviorally and physically these organisms would look like in the future due to these massive environmental transition. My project is just that, to take an in depth look at natural selection and some of the specific mechanisms and attributes to create an illustration with captions of what the rat population will look like in New York City after global warming has melted the ice caps. Through this medium, natural selection can be made more relatable through the use of a common existing animal as well as show how it is applied within the natural world. In addition, it will handle the actual threat global warming plays to our natural ecosystem.

Yet how do we know that climate change is accelerating natural selection? Natural selection, in it's simplest terms, is that the environment has factors that determine which organisms will survive and reproduce based on the traits of each organism. It is one of the key factors, in that it dictates which traits are successful variation and therefore which will be present in a population as it adapts overtime. We can see how human influence has affected natural selection by adding new hazard in an environment through examples like bacteria developing immunity to antibiotics or bugs with pesticides [1]. We can even see a direct relation between climate and variation on the genetic level. Labs have used *Drosophila subobscura,* or the fruit fly, to show that a change in climate increases genetic variation [2]. The experiment used fruit flies from a variety of regions and subjected them to climates a couple degrees warmer or colders from their natural ones. After a couple of generations, DNA was tested from these new flies and compared to that of the populations that were kept at their original climates. In the end, genetic variation between the control and the experimental group

not only increase in those populations who were subjected to warmer climates but in the colder climate groups too [2]. Not only that but all flies increased in genetic variation by almost the same amount [2]. The climate change in this experiment increased genetic variation due to the increased amount of advantageous mutation to adapt to the environment [2]. This may seem confusing as mutation is a very spontaneous process that should not be affected by the exposure to mild climate changes. In actuality, the rate at which mutations appear is unaffected, the change is the new environment where some of these mutations gives individuals a slight edge over those without. We can better show why through a study done on the Red Billed Gulls. These animals have been studied to show that due to Bergmann's Rule, which will be discussed later, as the temperature of their climate increase, the birds become smaller [8]. Although there were substantial changes in the average bird size, the genetic variation between offspring and child was constant throughout [8]. In both the case of the Red-Billed Gulls and fruit fly we see that the average genetic variation between direct off-spring and child is relatively constant [8]. When the climate changes however, those with variations that are advantageous for the new environment are more likely to reproduce and therefore become more prevalent due to these climate changes [2]. With this evidence that climate change causes dramatic changes in populations, we can look more deeply into how natural selection actually affects certain attributes.

Now in simple scenarios natural selection works like this: if a population is in an environment with X challenge those that have advantageous trait Y in response to X will usually survive and produce offsprings making possessing trait Y the majority in a population. Yet in application there is a lot more that needs to be taken into consideration. There are trade-offs for every trait [3]. An example is birds gathering foods for their young before they go back to the nest. They are leaving the young alone for longer and using time and energy foraging but the bird is also providing more food for them upon return [3]. These actions however have diminishing returns and therefore have an optimum balance of time foraging with time roosting [3]. This is not only present in the behavioral traits of organisms but also the physical traits. An excellent example of this can be seen in *Poecilia reticulata* or guppies. Male guppies that are brighter have a better chance of finding mates as they are easier to see and females are naturally attracted to them [7] Yet when presented with predators, the guppies became less bright over time, as those that were too bright were easily spotted by predators [7] This new environmental hazard created a cost for being more eye catching [7]. We see how a natural balance is found with the dimmer guppies as they are bright enough for females to see without being too visible to predators.

Knowing that traits have trade offs we now have to consider what is valuable in natural selection. This question of what is valuable leads us to the issue of senescence. Senescence, is an organism's natural life span and it is a necessity to be balanced for

an organism to be considered successful. As determining whether an organism is fit in the term of natural selection, an organism only really has to survive till it reproduces. This means that traits before the point of reproduction are far more valuable than those that are after sexual maturity [4]. Some organisms have traits that increase their fitness before sexual maturity but then lower fitness later in life [4]. This makes the race for sexual maturity able to greatly shorten an organism's life span and in turn inhibit their number of offsprings thus making the trait less successful in the scope of natural selection [4]. As an organism matures cells multiply rapidly, and as they do slight damages occur frequently every time they repeat themselves [4]. Although, not affecting the wellbeing of the organism at first, these can cause problems as they age older [4]. In humans, we can see this aging damage in the appearance of grey hair as the DNA becomes damaged from repeating so many times. An organism that matures faster therefore will most likely die faster as these genetic malfunctions will appear more commonly [4]. This evolutionary question of whether an organism should mature fast or slow is greatly dependant on how their life span will most likely be in there environment. A fly, for example, is preyed on by many predators and therefore will most likely die very quickly [4] In response, they mature in a very short amount of time and breed quickly to ensure their species survival [4]. An organism like a lions on the other hand, do not face as many predators or natural hazards and therefore is able to take a longer time developing and give rise to more offsprings [4].

With all of this in mind, we can now begin analyzing how the rats of New York City will change. For these prediction we are taking the ideas that rats stayed in New York until it was flooded and that they were able to adapt to the new environment as fact. Although there are some black rats present, the majority of New York rats are brown rats. The diet of these creatures in the present day consist mostly of scraps from garbage but they do have the ability to eat insects and some vegetation [11]. Most rats live in the subway or other secluded underground areas where they make their colonies. Considering there will be such a drastic change in environment and the population will most likely go down, so it would be best to talk about the current behavior in terms of a low density colony rather than a high density colonies as there are many different behaviors between them. Now a rat colony consists of many burrows of female rats called a nest [11]. This nest is then usually guarded by a male who fathers the children while the female rats actually raise the young [11]. The young rats reach sexual maturity in 5-7 weeks and usually disperse by this time to other burrows within the colony or a different colonies entirely [11]. The average lifespan is around 2 years and they can possibly reproduce more than 240 young in their lifetime [11]. The main predators in the urban area are predators like hawks, owls, and foxes but they usually remain fairly safe staying underground or in burrows.

This will change drastically as New York floods in the future. As seen in storms of the present day, when these tunnels flood colonies are going to be pushed to the surface leaving them more exposed to predators [11]. These predators will decrease average expected life spans and will give those with mutations to mature faster the edge trading off for a decrease in natural lifespan as a whole [4]. Besides lowering senescence, predators also will cause changes in the rodents' hues [12]. As seen with the rock-pocket mouse, depending on the environment, the rodents hues will naturally evolve to blend in and avoid predators [12]. For the rats in this case, they will become darker as the urban area of New York is a majority asphalt or abandon unlit buildings. These changes really have no drawbacks from a natural selection standpoint as color is not an integral part of rat mating [11] [3]. This change will occur gradually as even slight darkening of the fur will have an advantage and will be passed on to the next generation. In addition to color, more physical changes will occur. The average size of these new rats would decrease by Bergmann's Rule. Bergmann's rule states that animals in colder climates will be larger to keep energy inside their bodies while animals in warmer climates will be inversely affected becoming smaller [8]. The diet of these creatures would most likely be more insect and plant based but would still maintain its scavenger traits as a secondary source of food as it no longer has the abundance of human trash to eat yet still would be able to find half eaten corpses from animals like foxes or other predators. Once again this is assuming they would still be in the area.

My actual illustration will show both the present day rat and my predicted version showing how and why these changes happened over time. Visually I will show changes of hue and size as well as show their new environment. However, I can't effectively visually show all these changes. Writing wise, there will be some attributes that change such as, life span, and diet. I will also add explanations of how and why these traits change over time to further educate the viewer.

1)Thompson, John N. *Relentless Evolution*. The University of Chicago Press, 2013.
This book highlights human advancements effect on natural selection. Due to our massive effects on our environment on other organisms. This is things like antibiotic, pesticides, and environmental damage. All of these causes the deaths of many organisms who lack of variation cannot quickly adapt leading to rapid evolution of some species and the extinction of others. This also shows some charts on page 3 showing the different kinds of selection: stabilizing selection, directional selection and disruptive selection.

2)Balanya, Joan, et al. “Faculty of 1000 Evaluation for Global Genetic Change Tracks Global Climate Warming in Drosophila Subobscura.” *F1000 - Post-Publication Peer Review of the Biomedical Literature*, 22 Sept. 2006, doi:10.3410/f.1048324.500235.
This article shows how as environmental changes genetic variation changes as well. It uses the chromosomes of *Drosophila subobscura* (common fly) to show how genetic diversity increases as a species is forced to adapt to an increasingly changing environment. As temperature increased the flies had many more genetic changes than those at the regular local temperature.

3)Williams, George C. “Natural Selection, the Costs of Reproduction, and a Refinement of Lack's Principle.” *The American Naturalist*, vol. 100, no. 916, 1966, pp. 687–690. *JSTOR*, JSTOR, www.jstor.org/stable/2459305.
This article breaks down how natural selection works in a behavioral sense. It says that every action taken to reproduce has its own cost. An example is birds gathering foods for their young before they go back to the nest. They are leaving the young alone for longer but also providing for them. However, the author also brings up the fact that these actions have diminishing returns for the organisms. The time and energy spent on doing something like gathering food , takes time away that it could be doing other tasks as well as increase risk for the organism. That is why animals have a limited number of offsprings based on what they can provide for to ensure the maximum number of offsprings to survive.

4)Williams, George C. “Pleiotropy, Natural Selection, and the Evolution of Senescence.” *Evolution*, vol. 11, no. 4, 1957, pp. 398–411. *JSTOR*, JSTOR, www.jstor.org/stable/2406060.
This article talks about senescence, the natural life span of an organism, and its place in Natural Selection. The Article puts forward that traits sometimes are good for a certain part of an animal's life. However, a trait logically would mostly be need to help the organism grow to sexual maturity or for their reproductive cycle. An Organism's lifespan

is also controlled by their speed of development. If an organism develops quickly it is advantageous as it is more likely to survive long enough to reproduce. The trade off though, is that the production of cells happens quickly causing mistakes leading to aging and eventually death. This explains why animals that develop fast usually die fairly quickly as well, like flies and other insects.

5)Gadgil, Madhav, and William H. Bossert. “Life Historical Consequences of Natural Selection.” *The American Naturalist*, vol. 104, no. 935, 1970, pp. 1–24. *JSTOR*, JSTOR, www.jstor.org/stable/2459070.
This article is similar to the last one but brings population density into account. It also brings it to a much more mathematical and graphical frame of reference. Using mathematics still shows that sexual maturity is the most important period of an organism's life but it brings up that there is still a high importance on just simply being alive. It talks about the three biological processes that are part of natural selection; maintenance, growth, and reproduction. Although reproduction is the most important the other two still are advantageous and continue after they reach sexual maturity.

6)Lande, Russell. “Natural Selection and Random Genetic Drift in Phenotypic Evolution.” *Evolution*, vol. 30, no. 2, 1976, pp. 314–334. *JSTOR*, JSTOR, www.jstor.org/stable/2407703.
This paper is about analyzing the power of genetic drift vs that of natural selection in terms of the evolution of phenotypes. The general gist is that although natural selection does determine more, frequency of a random phenotype within a small population can sometimes present issues. If every organism needs the same resources it can cause too much competition. It also talks about the differences between density-dependant and density-independent. Density-dependant refers to selections factors caused by competition inside the same species. While density-independent refers to factors caused by outside forces like predators, environment, ect.

7)Endler, John A. “Natural Selection on Color Patterns in Poecilia Reticulata.” *Evolution*, vol. 34, no. 1, 1980, pp. 76–91. *JSTOR*, JSTOR, www.jstor.org/stable/2408316.
This article explores deeper into the natural selection of color patterns of animals, specifically the *Poecilia reticulata* (guppy). The article talks about how color changes between gender as being related to the X and Y chromosomes. This also bring to light what happens when there is a lack of predatory pressure. When the guppy’s were presented with no predators, they became more colorful over time as it attracts mates better, unlike those with predators who became closer to the same colors of their surroundings to hide from them.

8)Teplitsky, Céline, et al. “Bergmann's Rule and Climate Change Revisited: Disentangling Environmental and Genetic Responses in a Wild Bird Population.” *Proceedings of the National Academy of Sciences*, National Acad Sciences, www.pnas.org/content/105/36/13492.full.
This is a study of Red-Billed Gulls and the effects of climate change based on Bergmann’s Rule.
Bergmann’s rule states that animals on colder climates with develope larger bodies to keep energy within the organism and that inversely animals in warmer environments are smaller. As seen Bergmann’s rule is shown to hold true as New Zealand’s environment warms up. This also shines some light on the processes going on in source 2. In this article the it shows that mean breeding values, the value of deviation of the organisms being born, is shown to remain relatively constant. This shows that the rate in which genetic change is happening is not changing but is being pushed directionally.

9)GIENAPP, P., et al. “Climate Change and Evolution: Disentangling Environmental and Genetic Responses.” *Molecular Ecology*, Blackwell Publishing Ltd, 17 July 2007, onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2007.03413.x/abstract.
This article and study talks about microevolutionary responses and how it differs from plastic response and why microevolution is the major way organisms are dealing with climate change. Micro evolution means that there are small changes due to mutation in a specific population. It talks about how plastic response or just having slight changes to the already existing organism proves ineffective in the long run.

10)Yin, Jainjun, et al. “Model Projections of Rapid Sea-Level Rise on the Northeast Coast of the United States.” *Nature.com*, Nature Geoscience, 15 Mar. 2009, www.nature.com/articles/ngeo462.
This talks about how the North Eastern United states will be an area most affected by rising sea levels due to climate change. The article shares how through new advance SLR models we can distinguish with a greater accuracy what areas will be most affected by climate change.

11)Fragaszy, Dorothy M., and Susan Perry. *The Biology of Traditions: Models and Evidence*. Cambridge University Press, 2008.
This is an indepth look on rats traditional behavior and life as a basis for my rat evolution predictions. It talks about how their habits became more scavenger like due to coevolution. In addition, it brings up how they evolved a powerful digestive track to break down old or rotting food much like a vulture as well as their mating habits which is the female mating with many males. I also learned that they are a social animal that lives in colonies and brings food back for young.

12)Hoekstra, H E, et al. “Local Adaptation in the Rock Pocket Mouse (Chaetodipus Intermedius): Natural Selection and Phylogenetic History of Populations.” *Nature News*, Nature Publishing Group, 3 Nov. 2004, www.nature.com/hdy/journal/v94/n2/full/6800600a.html.
This article provides back for the changes in hues due to environment and predators as seen in rodents. This article specifically uses the rock pocket mouse and analyzes how the genetics slowly change over time as each small hue shift gives the last generation more of an edge than the first.