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Term Project Proposal: Mimicry

Since environments and ecosystems are always changing, adaption is crucial to all species in order to achieve the universal goals of survival and reproduction. Some animals adapt using a mechanism called mimicry, allowing them to copy the appearance of other organisms or of their immediate surroundings. One of the most peculiar and popularly-studied strategies of mimicry is color morphing [5]. Certain species of reptiles, insects, and amphibians have the ability to mimic each other through color change in order to hide from predators, or to attract potential mates. In most species such as certain frogs and butterflies, this change in color can be advantageous, as vibrant colors are evolved in order to indicate toxicity [2] [6]. However, these bright colors can sometimes be a disadvantage to other species, in that they are easily detectable and can result in a higher likelihood of predation. The most evident and observable mimicry through color change can be found in the chameleon, which can change the pigment of its outer layer of skin rapidly to serve the same purposes as other color-morphing species [8]. This is achieved through a complex dual-layered skin mechanism that can allows for a wide range of immediate pigmentation [9]. I have chosen this topic as my focus for the term project because I am interested in the physiological mechanisms of these changes, as well as how their functions differ from species to species.

The term used to describe mimicry involving color alterations is color morphing, or color polymorphism when referring to the presence of multiple traits related to this within an organism [5]. Color morphing is popular among scientists as an area of research because of its feasibility to observe and track [5]. It may appear that vibrant colors would become a disadvantage to certain organisms because they are easy to spot in the eyes of predators. In some cases, this is evident; while traits that are meant for a better chance of survival and reproduction are commonly selected, there tend to be some "design flaws" that occur in the evolutionary process [1]. These flaws are characterized by traits that may actually disadvantage a species and make them less likely to survive. For example, a species of insect called oblong-winged katydids, similar to grasshoppers, can exist in nature in a variety of vibrant, high-chroma colors such as orange and yellow [4]. This pigment change makes them more vulnerable to predators, as they can be spotted quickly and eaten. On the other hand, oblong-winged katydids that are green have more of a chance of survival, as they do not stand out against their predominantly-green environment as the other colors do.

Vibrant colors can be detrimental to the survival of a species due to their detectability and hindering of camouflage, but this is not always the case. In some frogs and butterflies, bright colors indicate that the species are poisonous. Other non-poisonous species can mimic these color patterns in order to deter predators, blending in with their harmful counterparts [7]. In these cases, color serves as more of a warning sign to predators than a way to hide. For example, butterflies of the *Nymphalid* species are poisonous, and possess a distinct color pattern in their wings to indicate toxicity to predators [2]. Other non-poisonous butterflies, such as those of the *Dismorphia* family, are able to mimic this same wing pattern in order to appear toxic to predators as well. In fact, most *Dismorphia* butterflies are mimics of the *Nymphalid* family [2].This type of mimicry is referred to as Batesian mimicry, meaning that an otherwise palatable species acquires the warning appearance of an unpalatable and harmful species [2].

Other species of butterflies display a different type of mimicry called Mullerian mimicry. In this case, two harmful species share the same traits that function as warning signs in order to deter predators. This is evident in Heliconius butterflies, whose wing pattern is a major signifier to predators that they are poisonous [6]. Since this trait was directly linked to the survival of these butterflies, it was selected and passed on to more removed species of Heliconius butterflies. While most Heliconius butterflies possess the same colors—red, orange, black, and white—the patterns of the wings differ between lineages based on the genetic structure of the trait [6]. The idea behind Mullerian mimicry is that successful signifiers of toxicity are likely to be favored through variations of the same equally-harmful species.

Mullerian mimicry can be observed in some poison dart frog species as well. The most harmful frogs possess color patterns of bright reds and yellows to indicate their high toxicity [7]. As predation levels lower due to this trait, it is selected and utilized in other frogs that live within the same habitat. In fact, there is a specific species of poison dart frogs called *Ranitomeya imitator* that is slightly less poisonous, generating a lower risk factor if consumed than its highly-toxic cousins [7]. It is classified as part of the poison dart family because of its similar-colored skin.

In frogs and in many other species as well, colors can be used as a reproductive advantage. Females tend to be more attracted to their male counterparts that are riddled with a more vibrant outward appearance, as it sometimes indicates that a male possesses a highly adapted genotype, which can influence a female's decision to mate with the male. In frogs, the trait of bright colors has not only been naturally selected as a way to avoid predation, but sexually selected as well in order to indicate reproductive success.

The process of color change in chameleons is a bit more involved because the mechanism of their trait is more complex. Rather than having a constant skin color throughout their lives that is used to ward off predators, they have the ability to rapidly change skin pigment based on their surrounding environment [8]. While it is evident that this versatile trait can be used to avoid detection from predators, it is also for social signaling [9]. In a study involving male dwarf chameleons, the chameleons expressed specific coloration in different situations such as asserting dominance over another male, or attracting a potential female mate [9]. The chameleons even expressed a dull "submissive" coloring when rejected by females [9]. This combination of both camouflaging and social capabilities is unique in chameleons, as most species must sacrifice their vulnerability to predators in order to display bright colors intended for attracting females or communicating within the species.

A versatile, multi-faceted trait such as this involves a much more complex process as far as molecular genetics and physiological mechanisms. In a study involving male panther chameleons, it was discovered that two layers of skin make this trait possible.  The first contains chromatophores, or cells that constitute pigment, that are riddled with nano guanine crystals [9]. These crystals can shift and form different patterns and lattices that result in changing pigments; the distance between crystals differed when the male panther chameleon was in a relaxed state as opposed to a defensive state [8]. To test this, skin samples from the chameleon were exposed to high pressure, causing the crystals to shrink, resulting in color change [9]. The second layer of skin is a constant pigment, and aids in reflection and absorption of light [9]. While it contains lattices that still play a role in pigment change, this layer is also responsible for thermal control.

Chameleons are unique because their exterior color can serve both camouflage and courting purposes, while in most other species, the two are mutually exclusive. I am interested in the immediacy of their ability to morph and adapt to their environment based on different social cues, as well as the technicalities of each layer of skin and how the expansion and contraction of guanine crystals allow new colors to be formed almost instantly. I can imagine these immediate changes being presented in animations, and aim to create a series of animated cartoon-style GIFs featuring a chameleon as the main character and showcasing some of its unique characteristics. I want to display each idea in a way that appears exaggerated, but still communicates the scientific aspects. For example, one GIF could feature a chameleon standing still in the center of the frame while its background swipes from one pattern to another, indicating a changing environment. Each time the background changes, the chameleon will change its appearance accordingly, displaying how chameleons change color based on social and environmental cues—not just arbitrarily. Another GIF could zoom in on the chameleon's skin and show an animation of the crystal lattices shifting to form another color, as the lattices themselves create interesting patterns and tessellations. The GIFs will either be compiled into a web page to be viewed all at once, featuring a small description or a link to another site that will explain what is happening, or they will be presented consecutively in a video.

The GIFs would be aimed toward an audience that uses social media frequently; I am imagining them as something that could be posted and shared online as both charming cartoons and as informative pieces. They would be created within the vernacular of the cartoon-style videos and comics that people stumble across on daily Facebook and Instagram. I want to simplify the GIFs in a way that would resonate with an audience who may have limited knowledge of mimicry in chameleons. We all know that chameleons are capable of changing color quickly, and we can infer that one of the main reasons for this is to hide from potential predators. But what most people do not understand is that this natural phenomenon has a "why" and a "how" that is equally as fascinating, and that there is a reason behind the beautiful colors we see existing in nature. The ultimate goal that I hope to achieve with this piece is to create a fun, educational, and fun animated piece that will spark interest in even the most unlikely audience members into the complex and fascinating realm of mimicry.

Annotated Bibliography

1. Barash, David P.  2008.  Evolutionary Design, or Why Bad Things Happen to Perfectly Good Creatures (Including Ourselves). Pages 16-20 in Natural Selections, First Edition.  New York, NY: Bellevue Literary Press.
This chapter discusses the “design flaws” of evolution, meaning how natural selection may end up complicating things in certain species compared to their predecessors. It gives the example of live birth in mammals, which happens with relative ease in most mammals, except for in humans, because natural selection eventually resulted in a narrow pelvic bone. It also gives the example of how our respiratory system and feeding system are combined rather than separated, which is why choking happens.

2. DeVries, Philip James. 2001. Butterflies. Urban Wildlands. Milwaukee Public Museum.
This section discusses both Batesian and Muellerian mimicry in different species of butterflies. For Batesian mimicry, it focuses on Dismorphia and Nymphalid butterflies, and discusses how the harmless Dismorphia family adapted similar wing patterns to the poisonous Nymphalid family because it was linked to their survival. It also mentions that most

3. Lakin, J.L., Jefferis, V.E., Cheng, C.M. et al. Journal of Nonverbal Behavior (2003) 27: 145.
This article discusses the “chameleon effect,” or the idea of mimicry without intention to mimic. This effect has transformed into a social function in humans, i.e. our ability to communicate, and a way of forming relationships. As chameleons non-consciously mimic their environment to blend in, humans non-consciously mimic other humans’ behavior in order to interact.

4. Linn, Shari, 2015. Oblong-Wing Katydids, *in* Featured Creatures, University of Florida, Florida, United States
This article features background on the Oblong-Winged Katydid and the numerous vibrant colors it exists in in nature. Obling-winged katydids are considered “false katydids,” as “true katydids” are characterized by a distinct wing shape. One considered to be a seasonal appearance, the uncommon colors are actually found to be a genetic mutation called erythrism.

5. McKinnon, J. S. and Pierotti, M. E. R. (2010), Colour Polymorphism and Correlated Characters: Genetic Mechanisms and Evolution. Molecular Ecology, 19: 5101–5125. doi: 10.1111/j.1365-294X.2010.04846.x
This article covers color polymorphism in general and how its uses differ from species to species. Evolutionary biologists are especially interested in CP because of its feasibility to track, and its variety of functions in animals. This article also goes into the genetic mechanisms and changes that occur in order to make color polymorphism possible. The study shows correlations between color polymorphism and the formation of other traits. For example, in certain butterflies, wing color patterns directly correlate with body size, whereas grasshopper body color correlates with predator avoidance.

6. Sheppard, P. M., et al. “Genetics and the Evolution of Muellerian Mimicry in Heliconius Butterflies.” Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, vol. 308, no. 1137, 1985, pp. 433–610., www.jstor.org/stable/2398716. This source delves into Muellerian mimicry, which is when a less-harmful species mimics the appearance of its highly toxic cousins in order to appear equally as harmful to predators. It gives the example of the Heliconius butterflies, and how their distinct wing pattern serves as their “warning sign” to predators. Since this trait increased the likelihood of survival for this species, it was selected

and passed through Heliconius butterflies of all toxicity levels. This source also delves into the genetics of the trait, and how wing patterns and presence of certain colors depends on genetic structure.

7. Siddiqi, Afsheen, Cronin, Thomas W., Loew, Ellis R. Interspecific and intraspecific views of color signals in the strawberry poison frog Dendrobates pumilio, Journal of Experimental Biology 2004 207: 2471-2485; doi: 10.1242/jeb.01047. This source contains information on the colors of poison dart frogs, and how they serve as warning signs to potential predators, indicating that they are harmful and unpalatable, and what happens when these colors are perceived by other species. I was able to use this source to provide another example of an animal that uses mimicry through color.

8. Stuart-Fox D, Moussalli A (2008) Selection for Social Signalling Drives the Evolution of Chameleon Colour Change. PLoS Biol 6(1): e25.
This article discusses the adaptive trait of color change in certain amphibians, reptiles, cephalopods, and chameleons, and how the trait differs among each. It focuses on chameleon color change, ranging from shade to actually chromatic change, and the idea that it is caused not only by natural selection but by social signals as well. This is tested comparatively, using dwarf chameleons to observe whether color change is based on crypsis or social signaling, or both, measuring the ability to detect signals by how closely they match the color of their environment. In the results, there was a direct correlation between detection of social signals and color change.

9. Teyssier, J. et al. (2015) Photonic Crystals Cause Active Colour Change in Chameleons. Nat. Commun. 6:6368 doi: 10.1038/ncomms7368
This study goes into the biology of chameleon color change, and examines the physiological change from one color to another in the skin of chameleon. Specifically examining the male panther chameleon of Madagascar and using a process called spectroscopy, researchers were able to examine the changing guanine nano crystals found in the chameleon's chromatophores, or cells that constitute pigment, during both a relaxed state and an excited state. They also examined the two layers of chromatophores in the skin. In the first layer, and found that there was a slight difference in distance between guanine crystals when the chameleon was in a relaxed state vs. an excited state, hypothesizing that the structure and placement of crystals contributes to color changes. To test this, skin samples from the excited were exposed to high pressure, causing the crystals to shrink. This caused a gradual change in color, concluding that as crystals within the chromatophores expand and contract, color change will occur.

10. Thompson, John N. 2013. Genomes. Pages 65-81 in Relentless Evolution, First Edition. Chicago, IL: University of Chicago.
This chapter provides an overview of the genetics of adaptation, and how the complexity of the change taking place will affect the time a species takes to adapt, and that selecting major vs. minor genes will affect this too. For example, if selection favors a large number of minor genes, the adaption process will become more gradual, whereas if it favors a small number of major genes, the adaptation process will be quicker. However, minor changes turn out to be more beneficial than major mutations. The adaption process also relies on the changing environment and can be slowed or sped up because of it. The chapter also touches on hybridization and how hybrids are less fit than their parent species.

11. Wenzel, John W., Carpenter, James M. (1994) Comparing Methods: Adaptive Traits and Tests of Adaptation: The Linnean Society of London
This article covers measuring adaption through probability and correlation. One section of the article focuses on the selection of crypsis in wasps as an adaptive trait. Wasps nests tend to camouflage with their natural backgrounds in order to deter predators from consuming offspring. It presents a hypothetical study in which tests this relationship between adaption and crypsis, observing the correlation between nesting on leaves and twigs and the tendency to blend in. The article also goes into the architecture of nest-building and how sites are selected in order to camouflage.