# The Cost of Beauty: Balancing aesthetic and adaptationist evolution

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## Introduction

In "The Evolution of Beauty", Prum (2017) argues that many of the ornaments present in animals need not have an *adaptationist* purpose (as is the common held belief), but can be the result of the aesthetic choice of the females. Focusing mostly on a variety of bird ornamentations, Prum uses a diverse set of examples that serve as convincing evidence that the aesthetic hypothesis is not only possible, but should be taken as the null-hypothesis, as opposed to the default belief that all evolved physical traits have some adaptationist purpose. Indeed, he shows a number of examples where the evolved ornaments in certain male bird species are actually *detrimental* for survival (as with the Club-winged Manakin), but are necessary because the females select mates based on these traits.

In this paper we present a simplified version of this theory by exploring the tradeoff between aesthetic and adaptationist evolution amongst a set of digital creatures. The resulting "living painting" provides an interactive demonstration of this tension. This was developed as a web application, which is availble at: https://cost-of-beauty.glitch.me. Although the images presented do highlight this tension rather well, it is best experienced by watching the animated evolution on the website.

## Mating and procreation

We have created a canvas of male and female Creatures that can mate and reproduce. When a Creature is born it starts out very small and requires some time to grow to maturity. All Creatures wander around semi-randomly, picking a new direction of motion with some low probability (based on a trait defined below). Upon reaching maturity, males will search for willing females to mate. If a willing female is found, the male will pursue the female by following the female's orientation. If the male is able to catch up to the female, they will mate for a few seconds, and then spawn children.

Each Creature has a "genetic code" consisting of a set of *traits* that determines its dynamics and appearance. Each trait is modeled as a normal distribution with varying mean $\mu$ and standard deviation $\sigma$. The defined traits with their ($\mu$, $\sigma$) in parenthesis are:
Size (pixels) $(20, 0.1)$; Childhood length (timesteps) $(2500, 2)$; Probability of direction switch $(0.01, 0.001)$; Lifespan (timesteps) $(40000, 5)$; Speed (pixels per millisecond) $(0.1, 0.01)$; Number of children $(8, 2)$; Mating duration $(2000, 30)$; Amount of red/green/blue (between 0 and 256) $(128, 35)$.

When a new Creature is born, each trait is sampled from one of its parents traits with equal probability. The only exception to this rule is in color inheritance, where females inherit their father's color directly (without mutation). Algorithm 1 details the process for setting the traits for a new Creature. For notational simplicity we use $\circ$ to denote a "coin flip" (e.g. $\circ(a, b)$ will return $a$ with 0.5 probability). We also denote $a \sim M.lifespan$ as sampling from the normal distribution given by $M.lifespan$; if we wish to copy the mean value directly, we use $a \leftarrow M.lifespan.\mu$.

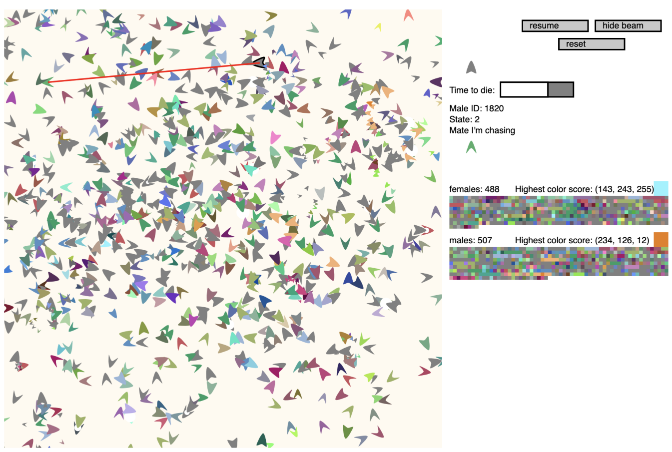
**Algorithm 1** Algorithm for creating new offspring

Given couple $M$ and $F$:
$numChildren \sim F.numChildren$
**for** $i \leftarrow 0 : numChildren$ **do**
  $creature.sex \circ (Female, Male)$
  **if** $creature.sex == Female$ **then**
    $creature.color \leftarrow M.color.\mu$
  **else**
    $creature.color \sim \circ(M, F).color$
  **for** $trait$ in remaining traits **do**
    $parentForTrait \leftarrow \circ(M, F)$
    $creature.trait.\mu \sim parentForTrait.trait$
    $creature.trait.\sigma \leftarrow parentForTrait.\sigma$
  Set $creature.direction$ randomly
  Add $creature$ to world

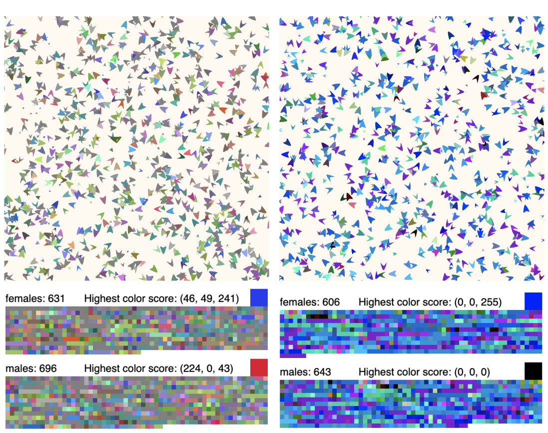
## Mate selection

Upon maturity, male Creatures try to "seduce" available females. Females can then decide to accept the proposition or not. Females do so by scoring the male's color. Specifically, if the male's color is given by $(r, g, b)$, the score will be: $beautyCost((r, g, b)) = |r - g| + |r - b| + |g - b|$.

This scoring function gives a low value to grey colors (where the red, green, and blue components are very similar), and gives a higher score to brighter colors. Until the accepted male is able to catch up to the female to mate, the female is free to switch selected mate if a more colorful male tries to seduce her. Note that the success of the male creatures is a function of the lifespan and speed of the male and female in question. In the web application one can select any creature and observe their traits, as well as the mate they're chasing. Additionally, the application shows the colors for all male and female creatures, as well as the highest-scored color. The following figure illustrates this (the red beam indicates a male in pursuit of a female creature):




To simulate the effects of overpopulation, if the total population exceeds 1600, we "wipeout" roughly half of the population. This not only helps reducing CPU burden, but also lends itself to interesting colour dynamics. Specifically, after wipeouts the surviving creatures tend to gravitate towards a specific set of colors. The figure below shows the canvas and color distribution before the first wipeout (left), and the canvas and color distribution after four wipeouts:

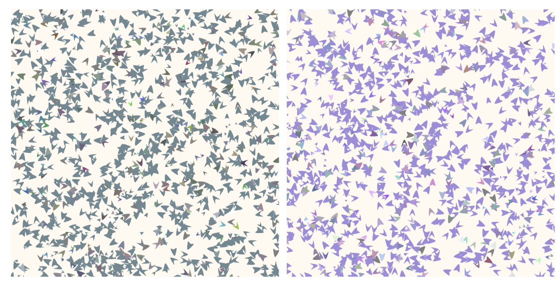



## The cost of beauty

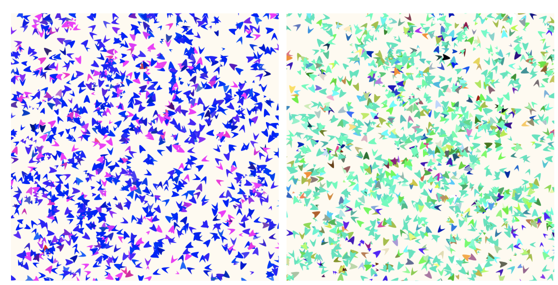
Unfortunately, being beautiful can be expensive. We reduce the length of life of the males by an amount equal to $beautyCost((r, g, b)) * beautyCostMultiplier$, where $beautyCostMultiplier$ is a value selected by the user. This multiplier allows us to directly control the tradeoff between aesthetic selection and adaptation: the lower the value, the easier it is to be colorful; the higher the value, the harder it is to find a female in time to reproduce.

We present a series of images snapshotted from our web application with three settings of the $beautyCostMultipler$: zero cost, mid cost, and highest cost. One can clearly observe the stark differences in color variety as a consequence of the selected cost of beauty.

When the cost is very high, we end up with a very grey palette (left); a mid-level cost results in a more colorful palette, but with reduced brightness (right):



In contrast, a low cost results in a very colorful world:



## Conclusion and Future work

This work explores the idea of leveraging the tension between adaptationist and aesthetic evolution for generating digital art. The simple mechanism used here is able to produce a playful and varied set of "living paintings". In the future we would like to explore more complex forms of selection, reproduction and physical dynamics. In particular, incorporation of flock dynamics could lead to more complex and interesting mating behaviours.

## References

Prum, R. O. (2017). *The Evolution of Beauty: How Darwin's Forgotten Theory of Mate Choice Shapes the Animal World–and Us*. Doubleday.