Recently, as I have begun to TA a course titled “Design Principles of Genetic Circuits,” I am able to take a step back and read textbooks and supplementary papers. This has unveiled so many questions and has made me admire biology and evolution. It’s remarkable. Truly, And I worry that not enough people are aware of this.

In this post, I’d like to just ramble, talk about examples of evolution I find stunning. Please reach out to me with more. Every time I hear of one I can’t seem to wrap my head around the intensity of it.

Most recently: genetic regulation. First, let’s cover the background information. DNA (genes) encode for proteins that we need for a variety of functions, including digesting food, breathing, and fighting disease. Before the DNA sequence that encodes for a protein, there is a promoter region. This is where RNA polymerase binds (remember that high school bio?!!) to make DNA into mRNA. Then, mRNA is made into the protein. In order to choose what proteins are made, there is genetic regulation. There are small molecules that control whether or not RNA polymerase can bind to the gene. We can have activators or repressors. When activators bind to the promoter, a shape change increases affinity for RNA polymerase, so the gene is transcribed. When repressors bind, RNA polymerase is blocked, so the gene is not transcribed.

Now that we’ve done basics. Let’s talk about the novelty. How does the cell know whether or not to choose an activator or a repressor? In what cases is it most efficient?

Let’s consider two categories of genes. First, we could have genes that we want to be on most of the time. These could be important and abundant proteins, like myoglobin, a protein that holds and transports oxygen in muscles. Would we want an activator or a repressor in this case? Is the answer different for the second type of gene: those that are off most of the time?

Indeed evolution has taken care of this. It is typically observed that genes that need to be on have activators and genes that are off have mainly repressors. The idea is that promoter regions are occupied most of the time in order to mitigate unwanted off-target interactions, such as phosphorylation, incorrect transcription factors binding, etc. How was this decision made? Evolution!

Mutations are the fundamental catalyst for evolution. If there was a mutation in a promoter region of a gene that needed to be on most of the time, and it was regulated by an activator. It would likely still bind, although weakly. But selection pressure would cause these types of genes to not proliferate at the same rate because efficiency will likely be lower. Explain this part better. However, if it was regulated by a repressor and a mutation occurred, it could increase binding affinity for a different, incorrect molecule that could bind. This would dramatically decrease the efficiency. This is the same logic that can be used for the regulation of a gene that needs to be off most of the time.