**Evolution and "Biology for Engineers"**

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Stephen Brush reiterated the need for evolution to be taught in high-school as well as in college-level courses. Evolution permeates my Biology for Engineers course taught at College Park. Not only do evolutionary principles explain many biological and psychosocial phenomena, but they also are predictive of future trends. Engineers who deal with living things need to be able to anticipate biological responses in order for their designs to be successful and to avoid unintended consequences of their actions. That living things react and adapt to new situations makes engineering using biological systems very challenging, but also very interesting.

Evolutionary principles can explain more than just responses of individual organisms. These principles make sense of actions of both competitors and cooperators, predators and prey, groups of individuals as well as single beings. New research into biofilms and quorum sensing confirms the portentions offered by evolution. Also, evolutionary principles have begun to be used by engineers, designers, and inventors as a tool toward product improvement. This technique is called directed evolution and involves random changes in the product followed by the selection according to some pre-agreed judgment criteria. The best variant is then caused to mutate, followed by another selection. After several of these cycles, an improved product results. Directed evolution has been used to improve microwave antennas, skyscraper buildings, and artificial enzymes.

The mistake made by Dr. Brush in his writing was to assert that evolution depends upon random genetic mutations. This same assertion is made by nearly all

evolutionists and has no real proof to substantiate it. There is even evidence to the contrary.

First of all, evolution does not depend on a genetic legacy. Information may be passed from one generation to the next in the biochemical nucleic acid form we know as genes. That is the classical means. For higher level animals, however, intergenerational information can also be taught and learned. This cultural information legacy is termed memes. It is known that adult birds and mammals communicate with the young to teach survival and reproductive skills. If that information is faulty, it does not get passed on because the recipients either die or don't reproduce. Evolution is just as much at work here as it is for genetic selection. Humans, in particular, use this method to improve survival of their young; that is why many of us are faculty at the university. Perhaps memes don't apply to microbes, but I wouldn't bet on it in view of the chemical communication means we are learning about microbes.

Second, there are regions of the genome that are more often mutated than others. These often occur during DNA replication and can involve looping and repetition. Some mutations occur orders of magnitude more often than others, and can even be predicted. Blood pathogens, for instance, can hide from their host's immune system by changing their outside coats. These changes are determined by the genes that control coat protein formation. Natural selection has favored biochemical mechanisms that alter just these genes and no others. These genes are located in areas bracketed by conserved sequences of bases; these do not change, but the regions between them do. Other examples come from venom production and antibody formation. Indeed, it appears that there is at least a second-order selection process in place that not only selects for genetic mutations leading

to the best survival and reproductive advantage but also to places in the genome that, if mutations were to occur, would then lead to survival and reproductive advantages. There seems to be a selection for those individuals that can mutate their genes in regions likely to improve survival.

Lastly, we come to the question of "why?" This cannot really be answered by science or engineering, but is an interesting contemplation nonetheless. Why did there appear at some ancient time chemicals that competed with other chemicals for resources in order to reproduce themselves? Once these chemicals appeared, a never-ending process was in place for evolution to proceed to and through the present. I have been amazed that these chemicals appeared in the first place. I'm no chemist, but I don't see other chemicals "behaving" in the same way. If the hand of God is present, it had to be when these protogenes first appeared.