A Lot to Think About, A Lot to Understand

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You will see in this issue a contribution from Mohammed Kiani in which he asserts that an understanding of evolution is an important and necessary part of biomedical engineering education. The conclusion that Dr. Kiani reaches is well reasoned and unequivocal.

I, too, teach evolution in my Biology for Engineers course, but permit me to give a few slightly different angles to the need for bioengineers to know and understand evolution and evolutionary principles. These are further explained in my book, *Biology for Engineers*, freely available on my web page, www.bre.umd.edu/johnson.htm.

In order to deal successfully with living things, bioengineers must understand that the biological objects of their attention are not passive objects like their books, glasses, or cell phones. Living things have the ability to react, to change, and to adapt, and even to attempt control of their immediate environments. The paramount objective of any living thing is to survive and reproduce, and it does so by any possible means at its disposal.

Adaptation passed on to succeeding generations is what we call evolution. It involves a semi-permanent change in essential characteristics of an organism. I say semi-permanent because nothing that I can think of in biology is permanent (not even death, on some levels).

If the characteristics of the living things you are dealing with change, then you had better understand the process of change: how it happens, why it happens, what contributes to it happening, and the results of it happening. There is no more of an issue here of *belief* or *non-belief* than there is with understanding that electrical current flows through a wire if I hook it to a battery. Evolution is a description of what can be expected when a population of living things is challenged over a transgenerational time span. Just as any living thing will adapt within limits of its capabilities, so will a population of living things evolve within its capacity to change.

Three necessary conditions for evolution to occur are: 1) genetic variation, 2) constant environment, and 3) a differential reproductive advantage. Without genetic variation, the capacity to change is limited or nil. Without a constant environment the necessary selection pressure will not be felt long enough for reproductive advantages of certain genes to be manifested. Going back to the paramount object of biology, we are talking about survival and reproduction, and the better the survival and the more fecund is the reproduction, the more dominant a certain genome will become. Again, there is no issue of "belief," just a mechanistic description of a long-term input-output relationship for living things.

Not only microbes have been induced to change. Fishing regulations in the Pacific Northwest have changed the median size of salmon, and our fruits, vegetables, and flowers are all much different from their native forms. Our cows are beefier and our lab mice have been selected to exhibit specific traits. Evolution, whether caused by human or nonhuman influences, has affected every part of biology.

What has gotten many evolutionists in trouble is their insistence that genetic variation comes about entirely as a result of random processes. They seem to have flaunted their own unbelief that there could be some creator behind this whole scheme of things. Well, genetic variation isn't entirely random. There are locations within the genome where mutations are more likely to occur compared to other locations. The places where mutations are more likely also appear to be the places where, if mutations do occur, they would lead to a disproportionate chance of a survival and reproductive advantage. So, it appears as if there are at least several levels of evolution at work: a level that selects for a tendency for advantageous outcomes and a level that selects for the advantageous outcomes themselves. Who knows if it is even more complex than this?

All of this I find fascinating, and like the laws of physics, a marvelous schema of predictability.

Lastly, I want to address the issue of human evolution, not in the past, but in the future. Recent evidence has pointed to improved capability of the human brain to process information, and so it may well be that our own species is still improving. Will another species evolve from humans? Not likely, because to form a new species a level of isolation must be present. In at least some physical or temporal domain, there must be a subpopulation with limited or no contact with the general population. Then, with genetic variation and constant environmental pressure (presumably different from that of the general population), competitive selection would eventually lead to a population whose members could no longer breed with members of the parent population—a new species. Humans are too mobile for this process to lead to a new species (at least on Earth).

It is more likely that human improvement will come from cultural information passed from one generation to the next (so called <u>memes</u>). If we look at the genome as an information repository, then books, videos, sound recordings, traditions, and common beliefs are other parallel repositories that can also contain information passed from one generation to the next. This information has as much chance of making permanent physical and behavioral changes in humankind as does information coded by the genes. In the future we are likely to see more effective information stored and used through memes than through genes.

It has long been recognized that biological systems are chaotic, in the mathematical sense. That is, the present state of an organism depends on its starting point and its history. Choices along the way result in magnified consequences. Some choices might not even be available if other prior choices were not made one way or another. The whole scheme appears to be random, but isn't. As long as the history of choices and influences could be reproduced, the end result is deterministic.

So, if biological systems are chaotic, and the outcomes are varied and almost unpredictable, how are we assured that individuals within a population don't continue to diverge from one another. Nam Suh, from MIT, has offered that birth of a new generation is equivalent to a resetting process. Each new generation (within limits) begins with the same genetic starting point as the previous generation. Each new generation is taught many of the same traditions, cultural beliefs, and educational skills as previous generations. So, although each life moves through a path completely different from all other life paths, we all start out from the same beginning.

There's a lot for an engineer to understand here.