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Grappling with 'Natural Selection' – Experiences of a Teacher

Since evolution forms the core of modern biology, teaching about natural selection is extremely important as this equips the student to frame the 'why' questions properly and, at the same time, sharpens their understanding about a host of issues pertaining to behaviour, diversity and genetics.

Evolution is the backbone of modern biology. The famous geneticist T Dobzhansky[1] once stated, "Nothing in biology makes sense, except in the light of evolution." The theory of natural selection, originally developed by Charles Darwin[2] and Alfred Russel Wallace[3], in its modern avatar, is the dominant paradigm of modern biology and therefore it's inclusion in teaching curricula and proper coverage is extremely important.

[1] See *Resonance,* Vol.5, No.10, 2000.

[2] See *Resonance*, Vol.14, No.2, 2009.

[3] See *Resonance*, Vol.13, No.3, 2008.

Till some years ago, I used to teach a course on vertebrate evolution and diversity to master's level environmental biology students at my university. The story of vertebrates, how they evolved from invertebrate ancestors, their radiation in aquatic environments and later their colonization of terrestrial habitats is a grand story of epic proportions. However, as a prelude, I touched upon the basics of evolutionary biology. During the course of teaching this subject, for more than a decade, a number of interesting experiences accumulated which I wish to share with other teachers in this article.

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– *Dobzhansky*

From a teacher's perspective, tackling the 'how' questions of biology is pretty much standard since much of the explanation can be done on the basis of basic physics and chemistry principles, which are not difficult to grasp. However, when it comes to the 'why' questions then a discussion of evolution inevitably enters the picture, making the teachers job a challenging proposition.

Keywords
Natural selection, evolution, biology teaching.

In the Beginning

Biology students would be expected to have a good understanding of the principles of natural selection but I discovered that this was not usually the case. So a general discussion began on how physical and biological systems differ; the capacity of living things to reproduce in a manner which is different from physical things (say, crystal growth) and their inherent complexity. How this complexity arose by a mechanism that has to do with heritability and differential survival of offspring, whether they be spores, seeds, eggs or cubs.

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Some broader concepts and ideas that people engaged with in the nineteenth century are worth recalling. For instance, Weismann's famous experiment of cutting the tails of mice, over several generations, which demonstrated the independence between the *germplasm* and the *somatoplasm* and that the former is, in a sense, a parasite on the latter. The physical body ages, dies and decays but certain sets of genes remain immortal [1].

Discussing 'evolutionary thought' is seldom possible without also bringing into the picture the general intellectual atmosphere prevailing in Europe then. For instance, the impact of voyages and accumulation of biodiversity wealth from different parts of the world into Europe and the intellectual atmosphere prevailing there for engagement of issues pertaining to life on earth. The most spectacular point for discussion is ofcourse Darwin's observations, both general as well as those accumulated on the voyage aboard the H M S Beagle, concerning heredity and variation, the concept of reproduction and increase of populations in geometric proportions, and the evidence of change having taken place, as evident from the fossil record.

Inevitably, discussions about the earth, and the formation of the universe ultimately lead to questions about intelligent design [2]. These issues continue to generate controversy even today. The famous evolutionary biologist and writer, the late Stephen Jay Gould[4], spent much of his career embroiled in the *creationist* versus *evolutionist* debates. I maintain that it helps to understand the reasoning behind it all if one pretends (if one is not already) to be an atheist. Of course the teacher cannot demand this attitude

[4] See *Resonance*, Vol.7, No.11, 2002.

from the students and one can only hope that they will follow the trail of logic and come to their own conclusions. In my classes I usually found student's attitudes somewhat ambivalent and could sense that most of them had not given such issues a serious thought. In their heart of hearts, probably many disagreed but said nothing, though I could at times imagine them saying, "Ok we will for the moment agree with what you are saying if you will give us good marks in the exam".

Occasionally, a student would come out openly against the evolutionist idea. I recall one, who held strong views about the biblical story of creation and maintained that God had created the world in seven days and all that science said about how the universe was created as unacceptable. Interestingly, there were also some students who were keen to reconcile and justify the 'scientific' theories about the age and formation of the earth, on the basis of their understanding of the epics and other religious and literary texts. This would be akin to putting things in different compartments so that questions of faith, belief and reason would actually never intersect.

Evolution of Adaptations

Demonstrating how natural selection works is easy. A useful contemporary example is explaining how a population of mosquitoes, which one assumes has 'variability' in terms of say pesticide tolerance (and the trait is heritable), develops the so-called 'resistance' to the pesticide over several generations. This example explains well differential survival and transference of traits. However, one of the most vexing ideas in understanding evolution is about adaptations. One is accustomed to thinking of adaptations in the sense of 'necessity is the mother of invention' or that adaptations arise, as if, out of thin air. The reality is quite different, though not necessarily complex. Equally confusing is the idea that in several cases, adaptations are not really efficient or perfect. The flawed structure of the vertebrate eye in which nerves and blood vessels obscure the passage of light to the photoreceptors and wrapping of the mammalian vas deferens

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around the ureter, like a person watering the lawn getting the hose entangled around a tree, are some classic textbook examples.

But the question really is how do adaptations arise? In their famous article 'The Spandrels of San Marco and the Panglossian Paradigm', Gould and Lewontin address this issue by taking examples from architecture [3]. Essentially, adaptations cannot arise at the drop of a hat but have mostly arisen from pre-existing structural frameworks, of which we see reflections in phylogeny. A well-known example is the evolution of jaws in fishes which came into being by a modification of gill arches of earlier primitive fishes.

Many 'Why' Questions!

In teaching basics of natural selection, initially, several questions seem puzzling and even insignificant. For instance, Why does the peacock have such a long tail? It seems to serve no adaptive function and is actually a handicap [4], so why is it there? If diseases like cancer have a genetic basis then why are those genes not eliminated by natural selection? How have such complex and specialized structures such as the human eye evolved? Is there altruism in the natural world? Why do women live beyond their reproductive life i.e., after menopause when they cannot produce more children? Under what (ecological) circumstances should a woman produce sons or daughters?

Then at a slightly different level, there is an entirely different set of questions about evolution itself. For instance, if evolution is powered by random processes then why does it appear to be directional – a transition from simple systems to complex ones? At what level does natural selection act: individual? population? clade? family? species? Is there such a thing as 'good of the species'? What is an evolutionary stable strategy? What are cheaters (in an evolutionary sense)? Gadakgar's book *Survival Strategies* [5] has dealt with such questions in a very nice manner and so I will not attempt to address these. However, I may mention only one very fundamental and often confusing issue, i.e., at what level does natural selection act? Expectedly, most

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students are likely to come up with the answer of species. Possibly the way evolution is introduced to us in high school books (terms like 'struggle for existence', 'survival of fittest', etc. – many of them being popularized by social philosophers like Herbert Spencer, who used human analogies to explain evolutionary ideas) makes us accustomed to thinking as if the struggle is between species. In my experience it takes some amount of convincing that natural selection, a silent, inert battle (if at all a battle) is not inter-specific but intra-specific, i.e., between individuals of the same species.

So natural selection acts at the level of the individual, but then comes a bomber. How do we reconcile the reproductive patterns of social insects like wasps and honey bees where all members of the hive are working for one individual, the queen? Does this not support the group hypothesis? Does it not make sense to talk of the 'good of the species'? The way out of course is a protracted discussion; how even Darwin was not able to give a satisfactory explanation to this phenomenon and one had to wait till laws of heredity were rediscovered and much later when modern biologists, particularly Hamilton[5] proposed the kin-selection theory and expanded the concept of 'fitness' (Darwinian or individual) to encompass 'inclusive fitness' (see *Box* 1). So, while it appears that the worker bees in a hive are actually altruistically helping the queen (for the good of the species!) in reality they are helping themselves, because of their genetic relatedness by a complex reproductive pattern to the queen. In the end, it is all a question of their not becoming a 'zero' when it comes to passing on their genes. They are themselves not participating in reproduction but since they are related to the queen, copies of the same genes as theirs are being passed on.

[5] See R Gadagkar, *Resonance*, Vol.6, No.4, 2001.

Such a discussion inevitably takes many twists and turns and the question about cheaters crops up. Suppose by mutation or some other mechanism an individual emerges who can take advantage of a stable situation and emerge a winner. There are several ways to deal with that and that takes us in the realm of 'theory of games' and how expected solutions are supposed to end, etc.

Box 1. Inclusive Fitness

Darwinian (or classical) fitness is defined in terms of how many offspring an organism produces and supports. The term 'inclusive fitness' being broader in scope, is the sum of classical fitness and the number of equivalents of its own offspring it can add to the population by supporting others. With inclusive fitness and by adopting a variety of strategies, say cooperative social behavior, an organism can improve its overall genetic success.

From the point of view of a gene (or a set of genes) evolutionary success ultimately depends on leaving behind the maximum number of copies of itself in the population. In the classical manner, it was held that this could only be achieved by an individual's ability to leave the maximum number of viable offspring (which would carry those genes). However, in 1964 W D Hamilton showed that, because close relatives of an organism share some identical genes, their evolutionary success can be enhanced if reproduction and survival of related individuals is ensured.

Hamilton devised a simple rule which predicts whether or not a gene for altruistic behavior will spread in a population. It can be stated as

$$rb > c,$$

where r is the degree of relatedness between the recipient of altruistic behavior and the altruist; b is the reproductive benefit to the recipient of altruistic behavior, and c is the reproductive cost to the altruist

During the course of teaching the basics of evolution I discovered that some examples are truly fascinating in that students are forced to think. The Grandmother effect, having emerged from a recent study [6] is a good example. The question is, why do women live long past the age of child-bearing? Contrary to common wisdom, this phenomenon is not new, and is not due to increased support for the elderly. Instead, as the authors suggest by a careful study of multi-generation records from two eighteenth- and nineteenth century populations from Finland and Canada, a grandmother has a decidedly beneficial effect on the reproductive success of her children and consequently on the survival of her grandchildren. This in turn has an impact on the evolution of longevity.

Conclusions and Recommendations

It has been said, "Evolution explains everything but predicts nothing". That may be partly true but from a learning perspective if the logic of evolutionary questions is followed it is a good mental exercise and equips the mind for sharper thinking on biodiversity, ecology, behavior and a whole lot of other issues in biology.

In my experience many students coming to the masters level course in biology demonstrated a poor understanding about natural selection and an inability to frame the 'why' questions correctly so that the same would be amenable for analysis in the light of evolutionary theory. This is probably reflective of improper teaching at the undergraduate (BSc) level. That students who had passed out from undergraduate colleges of the parent university fared no better suggests that here too the type of education imparted leaves much to be desired.

Some of the clever students who are good at solving problems often complained why a discussion on evolution was necessary. They argued that after all it was more important, as a professional scientist, to be able to know the methods of doing things: whether it is calculating, estimating or demonstrating something. Interestingly, sometimes even teachers appeared to think of evolution as an unnecessary distraction. Teaching protocols and textbook pathways and mechanisms is the preferred mode often leading to no questioning. They try to hammer down the message that in doing science there is only one method and that is the correct method. In the manner in which professional science is conducted the world over, learning the 'correct method' is no doubt important but equally important is to let students think, observe, question and explore freely.

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Suggested Reading

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