Model Essay #3

Constraints and Trade-offs in Evolution

In many ways it is helpful to think of evolution as nature's engineer. As an engineer, evolution faces the challenges of physics and of chemistry so that, for instance, the design of a horse's leg is guided and limited by the physical and chemical properties of bone, tendon, muscle, and skin. Evolution experiments with these materials (by means of adaptation) and, by throwing away almost everything it tries and keeping the tiny fraction that is most successful, creates a biosphere that is diverse and dynamic. This means that invention and change is arduous, and on top of it all evolution has a serious handicap. Unlike the human engineer, who solves ***for*** problems, evolution has to solve ***away from*** problems. In other words, evolution can only adjust to past mistakes with the materials at hand. She can't consider future benefit. Stephen Vogel says it best when he writes that nature "has precious little venture capital" (Vogel, 126).

So evolution has a whole host of limitations and stumbling blocks that make change difficult, imperfect, and often quite slow.[1] Bone requires constant upkeep and, while similarly dense, is weaker than aluminum (Vogel, 112). Bone's use is an imperfect adaptation. The large ground finch, ***magnirostris,*** can eat tougher seeds but must eat a lot more than smaller birds just to keep it's large body running (Weiner, 64). Its larger size is an imperfect adaptation. Change is difficult in nature. The main forces holding back change can be grouped into two categories: constraints and trade-offs. The lack of access to aluminum and its tendency to oxidize are constraints. The larger food needs for a bird hefty enough to crack tough seeds is a trade-off. Through the work of Jonathan Weiner and Stephen Vogel this paper will discuss how constraints and trade-offs shape the nature of change (and the change of nature) and how, amazingly, evolution continues to produce adapted individuals.

Limitations to evolution are what create stability. Change is difficult in nature. Perhaps the greatest limitation is the inability to look forward and solve ***for*** problems, but there are

others. It is difficult for animals to change because other species occupy the evolutionary niches that surround them. On the adaptive landscape, as Dolph Schluter would put it, any species is lucky to occupy the peak that it does, and there is little room to evolve because all the peaks around it are also occupied. Evolution probably serves mostly to keep species suited to their peaks, which are constantly changing themselves. But surely there are unoccupied peaks somewhere.

Think of Darwin's finches. One species drinks the blood of Boobies and of dead finches. What if it could evolve to occupy some sort of evolutionary spot between finches and the predatory hawks? Maybe there's no room here, but there very well could be. Let's say for the sake of argument that there is an unoccupied niche for a large, carnivorous finch. What limitations prevent movement into this niche? Lack of genetic variability is one factor. A small gene pool makes rapid change more difficult. The Grants seem to have uncovered a partial solution in the perpetuation of hybrid species, but in general lack of genetic variability is a major constraint.

Trevor Price discovered a limitation to the size of Darwin's finches that is illustrative of the myriad constraints limiting change found in the natural world. He found that, even when the environment was favoring largeness in adult birds, small ones were persisting. In fact, he found, the environment was simultaneously favoring smallness in juvenile birds and largeness in adults. Why? "Big birds need more food than young birds," explains Weiner, "and big juveniles need the most food of all, because they are still growing. But because they are young, their big soft beaks do not help them get it." Therefore, "while these birds are young, natural selection forces them in the direction of small size. When they get older, selection can force them in the direction of large size" (Weiner, 85).

So evolution doesn't change without difficulty, without first overcoming some serious constraints. When organisms finally do change, though, their changes involve bargains of a sort. A change that enables an organism to do one thing better makes it more difficult to do

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[1] When I say slow change I do not exclude dynamism. Darwin's finches change very rapidly, Rosemary and Peter

something else. All changes involve trade-offs. “It is obvious,” writes Darwin in ***Natural Selection,*** “that more descendants from [an herbivorous animal] could be supported in any country… if some were adapted to feed on tender grass and others on leaves of trees… and others on bark, roots, hard seeds or fruit” (Weiner, 143). In fact, this herbivore could pass on her genes most effectively if she were adapted to feed on all of the above sources of food. To be good at eating small, large, hard, and soft things would be ideal, but this isn’t the way it works. Individuals, in competition with others, have to specialize to some extent in order to feed themselves.[2] And, inevitably, specialization involves trade-offs. A beak that is good at poking and extracting isn’t good for crushing and cracking.

Vogel spends much of his book examining trade-offs of material and design. “Seeking a material with a desirable value of one property limits one’s choice of values of the other properties.” A brick is stiff and thus good for giving support and structure to a building, but it’s not very tough- concentrate even a small amount of force and it will crack (Vogel 92). These kinds of trade-offs put restrictions on change in nature and make all adaptations imperfect. Our teeth crack and chip relatively easily, for instance, but soft teeth couldn’t break down food very well (Vogel, 94). Similarly, an insect may be small enough to glide on top water, but can get stuck beneath it and drown. “The downside of being small enough to walk on water,” Vogel explains, “is being unable to get through the water’s surface” (Vogel, 49).

Trade-offs in evolution are often seen most clearly when sexual selection enters the picture. Being best at reproducing and being the best at surviving are often very different things and the behavior and physiology of individuals are often telling compromises. Take, for instance, Darwin’s finches. Among ***fortis,*** the medium ground finch, the plumage of males turns darker as the bird matures. “Black plumage indicates age and experience,” writes Weiner (Weiner, 88). And age and experience are attractive to females because male birds with more experience are often better able to protect the nest and thus raise the chance of genetic

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Grant have shown, but much of this movement is oscillation, not directional change. The natural world is buzzing and jittering in order to respond to an environment in flux, but species often change very little, slowly, or not at all.

[2] There are generalists and specialists, to be sure, but all species must specialize to a certain extent. Even generalists have to rule out most food sources.

success. But male ***for***tis fight with each other for territory during breeding times, and those in black are more of a threat and thus attacked by other ***fortis*** males more vigorously. And so, as a compromise, “a male that stays brown for a while may be able to avoid getting into so many fights, and set up its territory inconspicuously” (Weiner, 88). This is a serious trade-off, but one that some male ***fortis*** have to make.

Perhaps even more telling of the dynamic between the need to mate and the need to survive long enough to mate is seen in John Endler’s experiments with South American guppies. These guppies have bright spots of color on them and, depending on how many predators certain populations are exposed to, these spots are either prolific and bright or small and faint. The greater the pressure from predators, the fainter and fewer are the guppy’s spots because blending with the environment is critical. Endler noticed, however, that when pressure from predators is less, the spots become more prominent. Why? Weiner puts it simply: “the gaudier the male, the better his sex life” (Weiner, 91). So the guppies that Endler has studied are in constant flux; they are constantly walking the thin line between lack of camouflage and unattractiveness. “The quieter the colors of a male,” explains Weiner, “the less luck he has in courting females. On the other hand he is likely to have more time to try, because the less he stands out among his own kind, the less he stands out among his enemies” (Weiner, 91). So while most any change is a trade-off for an individual, it can be seen especially clearly when the imperative to breed and the need to survive are pulling the individual in different directions.

With all the constraints on evolution, and with all change requiring trade-offs of some sort, it’s a wonder that organisms can change enough to adapt to the environment. The nature of materials itself is a constraint that makes useful adaptations near impossible. Beaks need time to grow hard. Bones and teeth are strong but brittle. It’s amazing that nature has worked around these constraints. This is not even taking into account that genetic mutation and recombination, blind and relatively rare processes, are the sole source of change on which natural selection can act. Furthermore, any change that is preserved is a move towards one goal and away from another- it is a trade-off. This is seen most clearly, but by no means

exclusively, when sexual selection is urging organisms to stand out, but the predation environment is urging them to blend. So the constraints to change, and the nature of changes as trade-offs, make successful adaptation all the more extraordinary. But, it must be noted, the ability to change is one of the things that has always been selected for. Genes are here today because they have the potential for adaptive change. Why else would hybrid species persist among Darwin's finches when they are almost always selected against? It's because sometimes the adaptive landscape changes radically enough that without the genetic variation of the hybrids, the finches couldn't possibly survive. Change is difficult and changes are imperfect, but the ability to change must persist as long as organisms are to survive.