Appendix 1

AN ANNOTATED GLOSSARY OF EVOLUTIONARY TERMS

Adaptation {1. Definition. 2. Definition}
Biologists refer to the design produced by evolution driven by selection by the name "adaptation." However, this word is also used by psychologists to refer to a distinct but related phenomenon – the immediate adaptation of an organism to a change in environment. Both kinds of adaptation look like design; both kinds of adaptation fit an organism to its environment, both allow an organism to function in useful ways in an environment (typically several environments). The first kind of adaptation, the usual adaptation of biologists, the first kind of fitting the organism to its environment, is produced *across many generations*, never within a generation or within the lifetime of one organism. The other, older and commonly used meaning of adaptation, also a fitting of the organism to its environment, is adjustment to environmental conditions *within the lifetime of the organism* – through behavior, physiology, development, and phenotypic plasticity (these terms are not mutually exclusive). The two meanings of adaptation are related – in particular because the first kind of adaptation is what produces the ability to perform the second kind – but the two must be kept distinct because the processes producing them are so different. Selection and the grab bag of processes involved in immediate adaptation (behavior, development, etc.) had no basis for distinction until rather recently when Darwin brought to everyone's attention the process of natural selection.

The within-lifetime kind of adaptation has sometimes seemed relatively straightforward – it's not really, it's extremely complex, but it is readily visible during a normal lifetime and a matter of common experience – the bigger puzzle often seemed to be how organisms came to have such abilities, such design. Darwin's great idea described a mechanism for producing such underlying design that did not require a designer.

However, with more knowledge, it has become increasingly apparent that the processes of within-lifetime adaptation (behavior, physiology, development, and phenotypic plasticity) are not as straightforward as they sometimes appeared. For example, an organism may acquire traits (a) in the absence of experience (often referred to as "innate" or "hard-wired"), (b) despite almost any experience (also referred to as "innate" or "hard-wired), (c) only in response to a specific experience, or (d) the trait is adjusted in accord with current experience. The last two are often called "learned" and they do encompass real learning but they also encompass a great deal more. There is still a lot of confusion and discussion (much of it misguided) about these alternatives.

Much of such confusion boils down to misunderstanding the fact that adaptation produced by evolution produces the capacity for within-lifetime adaptation – even though most who make this mistake would likely deny they are making such a conceptually simple error. In practice the error often does not seem so simple – for example, the controversies over whether culture is, or even could be, adaptive or not have been almost endless.

In any case, we must discuss both kinds of adaptation and the processes that produce them. Usually the context makes clear which meaning is meant, but in a work such as this one, where both meanings must be used in concert, some uses are ambiguous. For example, the sentence "Adaptation produces adaptation" is a legitimate sentence with legitimate, and perhaps even correct, meaning – but the meaning may not be apparent without considerable background. If we use two different words, say AdaptationOne and AdaptationTwo, then the sentence has a more transparent meaning – AdaptationOne produces AdaptationTwo – which means of course, the adaptations produced by evolution over generations produces the ability for an individual organism to adapt to its environment here and now (sometimes using developmental decisions which may be permanent and take time to accomplish, and sometimes using behavioral decisions which are typically reversible and can be accomplished in a fraction of a second).

Behavior

Cultural "evolution"

Design: {definition}
Darwin proposed a process that produced design, yet had no conscious designer, no design goals or plans, and no intent. Darwin called this process natural selection. It was analogous to the often conscious selection humans performed on domesticated animals and plants, selection that Darwin termed "artificial." Later Darwin distinguished another type of selection, that which occurred in the process of acquiring a mate, termed sexual selection. However, although it is reasonable to keep artificial selection distinct – just in case what humans do with consciousness and planning is somehow fundamentally different from what nature does without those attributes – the varieties of selection occurring in nature, including the most commonly distinguished sexual and natural, have so much in common that it is useful in general to refer to them all as selection and to save the distinctions for more specific discussions when appropriate. We are going to abandon the phrase "appearance of design" to refer to the clear functionality of living organisms and instead just use the word design. We do this on purpose, even though it is not really correct, in order to emphasize that it is possible to have the appearance of design without a designer. The word is incorrect, of course, because the design process of humans is completely different from that of evolution. Human design is largely the result of conscious planning, learning from mistakes, and insight (though often enough there are admixtures of serendipity and inertia). Designs can be transferred from one realm to another – toys can become weapons, and weapons toys. Human designers may perfect parts first, or put together working parts from different sources. Evolution only works with fully functioning organisms, the modifications are produced at random, improvements are rare, different solutions to the same problem are typical, and poor (but workable) design is continually modified to get better. Evolution does not take what works in a bird and put it in a bat. Human designers, through a flash of insight, can throw an old design away and start anew, or design a thing from a glimpse of something else.

Evolution can only modify what it already has and throwing away a design means extinction. We trust the reader can readily remember not to infer too much from this abuse of notation.

Development {Definition}
This term is used by many people, including scientists, as a synonym for evolve, and it also has another meaning, the process of morphological and physiological change as an organism ages or changes habitats. Because physical changes are involved in each usage the two meanings are easily conflated. It is likely that develop is used to mean evolve by people wanting to avoid social and political friction. We do not use develop to mean evolve.

Gene {Definition}
As more is learned about genes and their properties they have become surprisingly hard to define – mostly because of the problem of retaining both generality and clarity in the definition. Regardless, the term is used in two ways, the second usage being perhaps not quite legitimate, but the usages are common and embedded in the literature. The two uses appear to have caused many .misunderstandings, often with the users apparently unconscious of any problem. One use of the word gene is to refer to the hereditary particles that are passed on during reproduction (they are not literally particles, of course, they are stretches of DNA, but they behave like particles because of the way the DNA is transcribed, and inherited). The problem is that these particles are not precisely the same in different individuals. Every gene has variants if you look throughout a population. These variants have a special name, they are called alleles. A gene may have two, five, 17, or whatever number of alleles. Each allele does more or less the same thing and usually the functional difference is small, in fact some of the variants have no functional difference at all. But sometimes the differences may be large. However, rare alleles for which the function of the gene is disrupted in a major way are the easiest for researchers to discover. The distinction between gene and allele is useful and important, but unfortunately many, including biologists in publications, refer to variants of genes as . . . genes. So if you see a news story that a cancer gene has been discovered – it is not that geneticists found a new stretch of DNA that had been overlooked until now, no, they found a new variant of a gene in some people who are prone to cancer. Everyone has (some version of) this gene, it is just that some people have an unusual and less-functional variant and this variant is associated with getting cancer. And the variant is called a gene rather than an allele or a variant, at least in the headlines.

Why is this such an issue? There are three reasons, two are matters of convenience, and the third is a serious logical problem. The first reason is that geneticists began discovering genes by discovering alleles of those genes that had serious mutations and so had dramatic and noticeable effects on phenotypic outcomes. This was a great way to get a handle on what was going on. They would then usually name the gene using a simple descriptor of the screwed-up phenotypic outcome of the mutant allele. This is also understandable, the focus was on the mutant and the name was convenient, but it has had unfortunate consequences that have never been rectified. Thus,. for example, *white* is the name of a gene affecting eye-color in the laboratory fruitfly, *Drosophila melanogaster*. It turns out the usual red color of fruit fly eyes is produced by the combination of two pigments, a brown one and a bright scarlet red one. *White* disrupts the biochemical pathway producing those pigments, so the eye ends up unpigmented and white. Actually *white* does not disrupt that pathway, *white* is involved in making an essential component of that pathway (a transport protein). The mutant version of *white* disrupts that pathway. But now the whole gene is named *white*, named after a very noticeable outcome produced by an unusual screw-up of the normal version. It's not too hard to grasp that *white* is critically involved in the biochemical pathway producing brown and red pigments, but it seems more difficult to avoid the almost unconscious inference that producing the color white is what *white* does. It doesn't, it produces the pigments brown and red. Only the much rarer mutant version is associated with the white color outcome. Fruit flies also have eye-color genes named *scarlet* and *brown*. *Scarlet* interrupts the brown pigment pathway (after it has divided from the shared beginning with scarlet, so the interruption does not affect the scarlet pigment) and *brown* interrupts the scarlet pigment pathway leaving brown untouched. So *scarlet* normally produces brown and *brown* normally produces scarlet. Got that?

This example is meant to highlight the importance of distinguishing gene from allele, but it is intermixed with the unfortunate naming convention used for many genes (the convention is used less often these days but it is still around). However, the naming convention is essentially a symptom of not being rigorous about keeping gene and allele distinct. Although one root of the naming convention was understandable convenience, it would have made a great difference if the early namers had kept in mind they were discovering alleles, and that it was through the discovery of misfunctioning alleles that they were discovering genes.

The mutation that led to the naming of a whole gene *white*, was only one allele of what turns out to be many. One problem is that the name reifies one rare allelic outcome and seems to imply that that is the normal gene's function. A second problem is that talks and articles become almost impossible to follow. The fruit fly example is among the simplest, yet imagine following an argument where *white* produces red, *scarlet* produces brown and *brown* produces scarlet.

The third problem is the serious one. Richard Dawkins wrote a famous and excellent book called The Selfish Gene. Although he explained himself carefully and his arguments are important and well thought out, his title remains one of the primary hooks for the whole set of concepts he covers. Yet "gene" in the title means allele (admittedly, The Selfish Allele would not have sold nearly as well). This leaves many people with an enormous misconception and a faulty inference. The misconception is that genes are selfish. They are not. Alleles are selfish, genes in the original sense of the word, the word with no synonyms (as variant gene and allele are synonyms) are in the vast majority extremely cooperative. It is alleles that compete (actually induce the phenotype bearing them to compete) for representation in the next generation. The genes, these places on the chromosomes that alleles compete to occupy are always there in some form or another in every phenotype, and they must cooperate in extensive and almost unbelievable ways in order to produce that phenotype. Your gene influencing the particular kind of collagen you have is not going all out in antagonism with your gene influencing the particular kind of myelin. It's the opposite, both are needed for a viable competitive organism, neither can succeed alone, and both are under layers and layers of regulation. No matter what particular kind of collagen you have (what collagen allele you have) and what particular kind of myelin you have (what myelin allele you have), you have a collagen gene and a myelin gene, and each is "interested" in the good performance of the other.

The faulty inference people often make from Dawkins' famous book title is the conclusion that selfish genes cannot produce cooperative individuals. As just explained, genes (in contrast to alleles) are actually highly cooperative – although this is not really directly relevant to the issue of cooperative individuals. Selfish alleles, or cooperative genes, can and do produce cooperative individuals. The reason will be covered extensively later because the issues of how many forms of cooperation there are, and what kinds humans engage in, are extremely important in human behavior and evolution. For now, we will just make the main point: cooperation is not an alternative to competition. It is an extremely effective form of competition. Cooperation is very common in the natural world, not just among humans, and genes (alleles actually) that influence an organism to be more cooperative or cooperative in more contexts, or more cooperative to certain kinds of other individuals, can and do spread.

Heritability

Reproductive Success: {Definition}
Survival of the Fittest is a phrase of Herbert Spencer's, not Darwin's. Darwin used it only with reservations and after much persuasion. If "survival" is taken as a metaphor for survival of a lineage through generation after generation, or taken as a statement about the survival of alleles through time, Spencer's phrase has more validity, but, it is too often taken literally as a statement about individuals, in which case it is literally wrong. The phrase has spread like the good sound bite that it is, and it has probably been a net help in getting across the idea of selection as a creative process, but it is fundamentally flawed as a real explanation as Darwin knew.

Survival of the fittest, and related shallow versions of Darwin's theory, was picked up by many of those who like to climb the ladder of power and wealth by beating down competitors (a perennially popular pastime enjoyed by members of every culture throughout history) as a convenient club for that purpose. If you were on the bottom of the social ladder you were necessarily unfit to be higher. Nature had placed you correctly (even though it was other humans who had forced you there). This perversion of evolutionary theory was known as Social Darwinism. This kind of misuse is no reason to discard the real theory, and such problems have occurred with almost every idea and technology. Many ideas and technologies can be used for good or evil, depending on who has their hands on the lever, keyboard, or checkbook. Today people still misuse and misrepresent Darwin's ideas because a quick and dirty version of them seems useful for whatever oppression is currently being attempted.

Of course the other big problem with Survival of the Fittest is that it emphasizes survival. Because we are humans, we have evolved a slow reproductive rate, and we expect to reproduce repeatedly during the course of a lifetime. Crudely, for us, a longer life leads to more reproduction and the urge to personal survival is extremely strong. But the basic process favored in evolution is reproduction, not survival. Individual survival makes a big difference only if you haven't reproduced yet, or if you have a high expectation of repeated reproduction. Humans do expect to reproduce repeatedly over many years, but for many organisms that is not the case. Many insects in temperate climates, for example, do not overwinter as adults – it is too chancy – rather they reproduce and die, and the overwintering stage is a larva or an egg. Annual plants overwinter as seeds. There are also many organisms that live many years but have evolved to reproduce only once in a lifetime (e.g., salmon, some bamboos). Every organism that reproduces only once dies right after reproduction, or after its parental care is done (which is the true end of reproduction). Whatever pattern of reproduction has evolved, whether or not continued survival near the top of the list of reproductively valuable activities, the issue is still basically the same. Organisms are mortal, and even if they didn't age there is still a high chance of death at some point from predators, parasites, warfare, floods, droughts, volcanoes, whatever. Those that reproduced before getting nailed are those that have had an imprint on what is around in subsequent generations. The imprint made by surviving without reproducing lasts only as long as the individual. The one possible exception is humans – given the importance of culture and learning in putting an imprint on the human future.

Reproduction is more than sex. Women know this. Men can find it a bit puzzling, even though most have to go through a lot of effort just to get to a place where they might have a chance at sex. Once men try their hand at parental care it becomes clear immediately. The issues are basic. Resources above and beyond those needed for survival are needed for reproduction. That extra mass that goes into kids, even if all you do is lay some eggs and walk, swim, fly or slither away, has to come from somewhere. If parental care is involved, extra time and energy are involved as well as extra physical resources. In addition, every organism has evolved to reproduce at much more than the replacement level. Even the slowest reproducers such as elephants and albatrosses can overwhelm the world with descendents given the chance. The corollary is, of course, that every organism has the capacity to out-reproduce its resource base.

The need for extra resources for reproduction, above and beyond those needed for personal survival, provides another set of examples of how reproduction is more valued by organisms than survival. Much evidence shows that is that reproduction often has primacy over survival if an attempt at one precludes the other. Although the impulse to survive is exceedingly strong, it is often superseded by a more important impulse – that is, to save or make new relatives, most often offspring (although one of the many unusual traits of humans is that they can help save or make many different kinds of relatives in many kinds of ways). That is, survival is often sacrificed for reproduction. Whether or not such a sacrifice is made depends on the probability of reproducing successfully again if reproduction is (temporarily) forgone

An aspect of this is the universal contest for resources that organisms engage in. For critical and limiting resources (there are always such, for every organism), access to more resources leads to more reproduction (there is an interesting and important exception to this for modern post-industrial humans). Without access to the amount of resources required for reproduction survival may be possible but reproduction is curtailed. Every organism has evolved to seek, compete for, and use as many resources as it can typically turn into offspring. Often resource acquisition has evolved to be open ended – resources that can be defended from others are defended, even though the defender may never be able to make complete use of them.

Selection: {Definition}
(Several kinds, should be viewed basically as one)