UNIVERSAL ASPECTS OF BIOLOGICAL EVOLUTION

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ABSTRACT. Which biological laws, if any, might be universal?

Astronomy and astrophysics are based on the assumption that the laws of physics and chemistry, as we understand them, hold throughout the galaxy and the universe. To what extent this assumption is tested by experiments and observations is a subject of continuing debate. But if, as some of us believe, the laws of biology are ultimately based on the laws of physics and chemistry, then we might suppose that at least some of the laws of biology, as we understand them, also hold throughout the galaxy and the universe. This geomorphism, like anthropomorphism, is sometimes justifiable, sometimes just wrong. But some of the arguments for some of the laws of biology are, if correct, then universal. Among candidates for universal biology are, first, the most fundamental law of all--mutation and natural selection through survival of the fittest--and also sexual reproduction, speciation, intraspecific competition, interspecific competition, predation, parasitism, and symbiosis.

Ten minutes is time to try to sell only one or two quick ideas. I would like to convince you that: (1) the concept of progress can be defined in a fairly precise way, (2) Earth's fossil record shows that progress has occurred, (3) even after Darwin we really don't understand why, but (4) we can approach the problem by considering the differential survival of replicators called genes and memes, and (5) a reasonable extrapolation of the trend predicts continued progress for Earth's biosystem and presumably also for other civilizations.

I've previously suggested (Ball, 1980) that a level-of-development parameter can be defined as the logarithm of the total information content (in bits) of the biosystem. This information resides in genes, brains, and extrasomatic memories such as libraries and magnetic disks. One must carefully account for redundancy; two copies of the same gene or the same book are worth only a few bits more than one copy. Progress is defined as an increase in level of development. Figure 1 is a crude attempt to show Earth's history in these terms.

M. D. Papagiannis (ed.), The Search for Extraterrestrial Life: Recent Developments, 251–254,

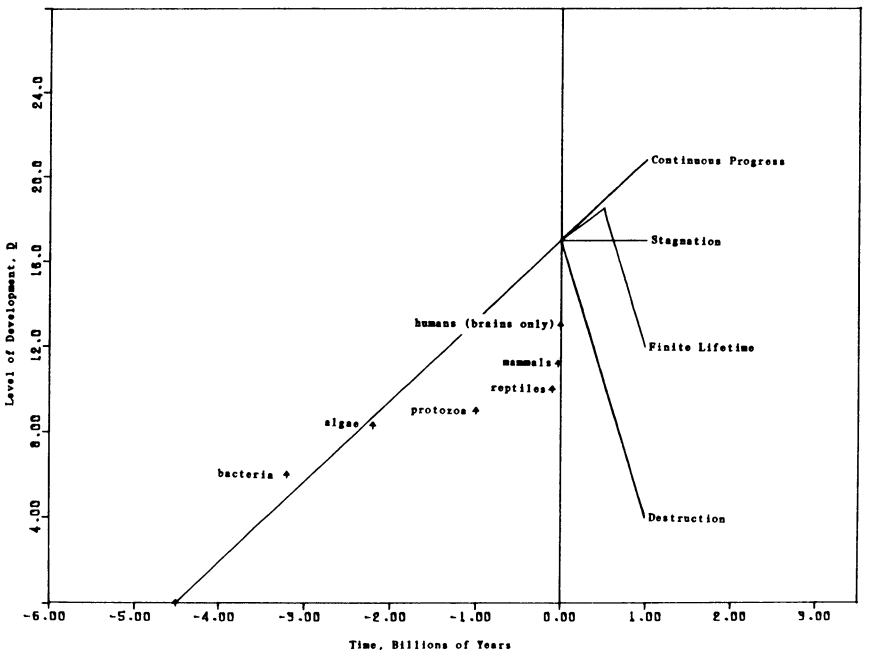

Figure 1: On the vertical axis is level of development, D, which is the logarithm to the base ten of the total biological information in bits. As with thermodynamic entropy, there are problems in defining the zero point of information entropy. The definition of D is, in any case, crude. The horizontal axis is geological time in billions of years before the present (B.P.). Some significant events in Earth's history are indicated, as are four possibilities for our future.

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Even a cursory examination of the fossil record firmly establishes the phenomena of evolution. From no fossils in the oldest rocks through single-celled organisms, then wigglers, eaters, creepers, crawlers, swimmers, runners, flyers, thinkers, up through the evolutionary sequence--more species, more diversity, more complexity: four-and-a-half billion years of unsteady progress. Even if it is an ill-defined concept, there is overwhelming evidence for something happening that we label progress.

The phenomena of progress are well-known; the explanation is not. We don't understand very well the origin and evolution of life on Earth and we don't know whether life is common or exceptional in our galaxy in part because we don't have a theory to apply to such phenomena. Darwin himself and many modern evolutionists repeatedly emphasize that natural selection predicts local adaptation and evolution but not global progress. No theory does.

At the risk of oversimplifying, I would argue that what biology is all about is the differential survival of potentially immortal replicators called genes and memes. These replicators are, strictly, instructions--a category of information--rather than, for example, DNA, RNA, or paper, which are media on which replicators are written or by

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which replicators are propagated. These replicators are instructions for doing or making things, such as the behavior and morphology of organisms. A successful replicator is one that somehow promotes its own survival and propagation in the prevailing environment, or sometimes, manages to alter the environment to promote its own perpetuation. The metaphor of pupose--genes and memes function as if their only (teleonomic) purpose were to propagate and perpetuate themselves--is a rarely deceptive and often powerful way of thinking. Since the differential survival of replicators is so fundamental, I suggest it as a good (maybe the best) candidate for universal biology.

Genes are units of information usually stored in the nuclei of cells; memes are units of information sometimes in brains, sometimes in books. An archetypical meme is a recipe, say, for baking a cake. A recipe can exist in mind or on paper or both. Recipes are pleiotropic memes (many memes are pleiotropic) with two phenotypic effects or meme products: baking (behavior) and cake (artifact). In most cases, the cake is the desired product; the baking is undesirable in the sense that if the cake could be obtained some other way, then the time, effort, and materials needed for the baking would be saved for some other use. This is not to deny that some people enjoy baking; but how long would they continue to bake if no cakes or inedible cakes resulted?

Suppose a person uses a recipe to bake a cake. If he likes the cake, he keeps the recipe, uses it again when he wants another cake, and maybe shares cake and recipe with friends. (Unlike cake, you can have your memes and share them too.) If he doesn't like the cake, he discards the recipe, marks it "no good," or at least modifies (recombines or mutates) it before trying again. If, however, the cake is accidentally damaged, say because the oven failed (a conculinal defect), the recipe is unaffected unless the cook doesn't realize what happened; he might throw out the recipe inappropriately. This process is closely analogous to artificial (genetic) selection of domesticated plants and animals. Memes and genes follow very similar rules of evolution.

There is, then, a strong analogy between genes and memes, and many of the well-known ideas about genetic evolution can be translated into memetic language (Ball, 1984). Genetic evolution and cultural evolution are two aspects of the same problem, but we don't really understand either aspect.

What is needed is a unified general theory that contains Prigogine's dissipative structures in non-equilibrium thermodynamics, the origin of life and biological systems from non-living material, Darwinian evolution by mutation and natural selection of replicators, and progress through accumulation of information in hierarchical structures up through civilizations, all as special cases or corollaries. Such a unified general theory would define a level-of-development parameter for a system probably in terms of its useful information or instruction content, define progress as an increase in level of development, and then specify the conditions under which progress is certain, likely, unlikely, or impossible.

Alas to say, such a theory will need to be written by someone cleverer than I.

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