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In his satirical novel of University life, *Changing Places*, David Lodge writes of a game played by Professors of English literature, in which each player is challenged to confess that he or she has not read some well known literary work. The players are stunned into silence when one of them confesses to never having read Shakespeare's *Hamlet*. Were evolutionary biologists to play a similar game honestly, they would almost all confess that they have not read Darwin's *Origin of Species* from beginning to end. Some of the most honest of them would admit to never having even opened the book. Yet Darwin is the most famous biologist who ever lived. Reference is made over and over in both scientific and popular writings to "Darwinism", "Darwinian evolution", "Darwin's theory of evolution", and "the Darwinian revolution" and he is usually described as the founder of evolutionary biology. In the process of identifying "evolution" with Darwin there has grown up a large body of misunderstanding of the place of the *Origin of Species* in the history of the idea of evolution, of the role of Darwin's work in the justification of what came to be called "social Darwinism", of Darwin's analysis of the process of organic evolution and, ultimately, a confusion about the meaning of "theory" in science.

Darwin certainly did not invent the idea that life on earth has evolved from earlier forms that are now extinct and will continue to evolve in the future. The idea of evolution had already become common in Europe since the beginnings of the bourgeois revolution in the eighteenth century. A hundred years before the appearance of the *Origin* in 1859, Denis Diderot, in his *The Dream of d'Alembert* has his philosopher ask in his sleep "Who knows what races of animals preceded ours? Who knows what races will succeed ours? Everything passes, everything changes. Only the totality remains." Tennyson, in his epic poem, *In Memoriam* asks whether Nature is "careful of the type" and answers:

"So careful of the type?" but no.  
From scarped cliff and quarried stone  
She cries, "A thousand types are gone;  
I care for nothing; all shall go."

Even Darwin's grandfather, Erasmus Darwin gave an evolutionary view of the origin of all organisms from "rudiments of form and sense" in his *Temple of Nature* of 1803. Charles Darwin lived, worked

and wrote in an era of rampant evolutionism, an evolutionism that was an intellectual manifestation of the rise of an entrepreneurial bourgeoisie conscious of the social and political revolutions that had brought them to power. So, the mid-nineteenth century English social philosopher Herbert Spencer argued that the best evidence for the truth of organic evolution was that stars, language, political structures, social relations and everything else evolved. Evolution was seen as a universal law of the universe.

It was precisely the popularity of ideas of instability and evolution that led to the buying of every printed copy of the *Origin* on the day that it was issued.

The usual explication of Darwin's view of the mechanism underlying evolutionary change as presented in the "Origin" puts very great weight on the role of the competition between organisms for resources in short supply. Such explications place great emphasis on the impact that Darwin's reading of Malthus had on his idea of natural selection. On this view natural selection operates because organisms tend to increase in number geometrically, while the resources for their maintenance and reproduction are either increasing only arithmetically or not at all. The forms that are more "fit" for the struggle win out and their types increase in the species. This view of the "struggle for existence" is one in which the model is an active physical competition between organisms to determine which of them will win and which lose, as, for example, when two animals fight over a bit of food or two males compete for access to females. It is undoubtedly true that such contests for resources are an important part of the mechanism of natural selection envisioned by Darwin. But he is careful in the *Origin* to make a broader claim. He writes that

"I use the term Struggle for Existence in a large and metaphorical sense including dependence of one being on another.. . Two canine animals in a time of dearth may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against drought .. ."

For Darwin the struggle is the struggle to survive and reproduce irrespective of whether other individuals are competing for resources in short supply. Among the modes of struggle are cooperation between individuals and groups and symbiotic relations ("the dependence of one being on another").

One of the misunderstandings of the history of evolutionary theory, and of Darwin's writings in particular, is the claim that a result of the publication and popularity of the *Origin* was the later development of "social Darwinism", the extension of the idea of evolution by natural selection to the

realm of economics and politics. But this turns history on its head. In the *Origin* Darwin imports into biology the reigning nineteenth century notions of economic struggle, of the rise of a new stratum of entrepreneurial actors who survive and increase their power and property by virtue of their superior competitive fitness. "Social Darwinism" preceded Darwin and we would more correctly think of the "Origin of Species" as the inheritor of the idea of survival of the fittest, as a form of "biological economism".

If Darwin did not invent the idea of "survival of the fittest" nor the idea that organisms have evolved, what was his fundamental contribution to biology? There were in fact two essential innovations that revolutionized biological thought and that have characterized it since 1859. The first is Darwin's emphasis on the variation among organisms as integral to our understanding of evolution. There are two schemes that characterize the structure of the modern scientific understanding of the temporal change in physical systems. One is a *transformational* scheme in which the ensemble of objects changes because every object in the ensemble is undergoing the same change through time. Kant and Laplace already in the 18<sup>th</sup> Century had postulated an evolution of the universe. We now know that the ensemble of stars in the known universe is undergoing an evolution in average luminosity and density because every individual star will go through the same stages of the nuclear cycle, becoming a red giant of great size and luminosity and low density, and then finally shrinking down to a dense blue dwarf. The other scheme of evolution is a *variational* one in which the ensemble changes, not because each individual changes through time like aging stars, but because there is variation in properties among individuals in the ensemble and some of these variants survive and reproduce similar individuals while other variants die out. As far as we know biological evolution is the only example of a variational evolutionary system, although it is now fashionable among social theorists to create variational evolutionary schemes for human culture. It is the variational scheme of organic evolution that differentiates Darwin's insight from the transformational theories like that of Lamarck, which postulated evolution by the physical transformation of individuals over time through their striving toward some end. In putting variation among individuals at the center of his view of nature, Darwin not only presented a new and original view of how evolution occurs, but reoriented the way in which we describe and understand the ensemble of organisms. Biologists no longer see individual members of a species as imperfect variants of an ideal physical type of that species. We now understand that variation among individuals in a species is the biological reality and that the grouping of such variant individuals into a species is a secondary consequence of their ecological and reproductive properties. For Darwinian biology, variation is of the essence.

The second fundamental break with previous biological understanding that is contained in the *Origin* is Darwin's separation of the effect on the organism of internal as opposed to external causes. For Lamarckians any changes in the organism induced by external conditions were incorporated permanently into the internal state of those organisms and passed on to future generations – the inheritance of acquired characters. The argument of the *Origin*, that biological evolution is a variational process involving the differential reproduction of favorable variants, rather than the

cumulative alteration of individuals by repeated exposure to environmental molding, depends on this separation of internal, heritable, causes of variation from temporary non-heritable alterations to the body of the organism from external causes. This separation should not be confused with the claim that genes and environment are separate causes in the development of an individual. The phenotype of any individual is, of course, the consequence of the interaction between genes and environment during development. The issue is whether changes in phenotype induced by environmental forces can be themselves inherited.

Finally, and most relevant for the political situation in which evolutionary biology now finds itself, we must consider what is meant when we speak of "the theory of evolution." The word "theory" is ambiguous. It has three quite distinct meanings. In one meaning it may be simply a system of abstract propositions connected by logical and mathematical relations with no particular relation to material reality. This is the meaning of "theory" in the name "Matrix Theory" for a branch of the mathematics of multidimensional variables. Or, for the world of observed phenomena it may mean simply a hypothesis, made up to explain some set of observations, but without any compelling evidence that the explanation is true, as in the expression, "It's only a theory." The third meaning of theory, used in science, is a set of rigorous formal connections between physical forces and physical states that make it possible to predict and calculate how a particular force of a particular strength will produce a particular measurable result. Darwin's "theory" is that sort of theory. The importance for biology of distinguishing the second from the third meaning of the word "theory" lies in the ambiguous use that the supporters of special creation and intelligent design make of the phrase "the theory of evolution." They want us to understand evolutionary theory in the sense that it is "only a theory" and therefore not entitled to any greater credence than any other hypothesis that may be put forward to explain the history and diversity of life on earth. But the theory of evolution in its modern form is a theory in the third sense, a structure of quantitative relations that enables us to measure and predict the evolutionary outcome of particular material biological forces. Evolution is a fact and the theory of evolution is a deductive scheme that connects the various known material causes that influence that fact. The claim for example, by the proponents of intelligent design that the exquisite complexity and functionality of complex organs such as the eye cannot be explained by unplanned material forces is incorrect. Darwin's theoretical explanation of such organs of "extreme perfection" was that they did not arise at a single step, but were the accumulated result of small changes each of which added something to the functional properties of the entire organ.

Everything that has been learned since about the genetic basis of the development of different parts of the eye, for example, substantiates this Darwinian analysis.

The "Origin of Species" is a rich and complex scientific document that will repay reading from beginning to end. It is particularly important in a time when the scientific understanding of the history of life is under attack that we do not emulate the Professor who had not read Hamlet. *The Origin of*

*Species* should be read carefully from the first to the last page if we are to have correct understanding of how, as Darwin writes at the end of the “Origin”,

“from so simple a beginning endless forms most  
beautiful and most wonderful have been, and are  
being evolved .”