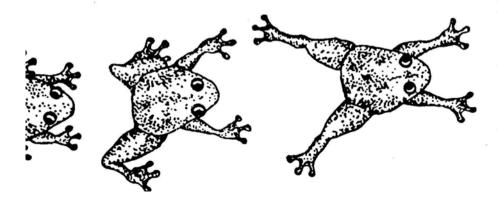
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THE GENE AS THE UNIT OF SELECTION: A CASE OF EVOLUTIVE DELUSION

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INTRODUCTION

Since the enunciation of Darwin's theory of natural selection, the question of which one is the unit of natural selection has been debated both by biologists and by philosophers. The unit of selection is the concept of that 'something' to which biologists refer when they speak of an adaptation as being 'for the good of' something. However, some philosophers consider that the nature of the unit of selection is metaphysical and thus beyond any positive scientific debate ¹. Nevertheless, among the modern followers of the synthetic theory of neo-Darwinism, which is a blend of the theory of natural selection and the basic postulates of Mendelian genetics, the question of the unit of selection is regarded both as truly scientific and of the foremost importance. Indeed, since 1966, George C. Williams—whose book *Adaptation and Natural Selection* was the rallying cry for the current movement of ultra-Darwinism ²—posed the need to develop a rigorous science of adaptation, called 'teleonomy' (following

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the original suggestion by Pittendrigh 3), whose central theoretical problem should be that of the nature of the entity for whose benefit adaptations may be said to exist. Later on, Richard Dawkins, who is by far the most gifted populariser of the ultra-Darwinian view 4, coined the term optimon as a shorthand substitute for the unit of selection 5. Therefore, it seems justified to assume that a very important question in current evolutionary theory is whether adaptations are for the benefit of the individual organism, for the benefit of the group or species, or for the benefit of some smaller unit inside the individual organism. As Dawkins has rightly pointed out: adaptations for the good of the group will look quite different from adaptations for the good of an individual 6. The identification of individuals as the unit of selection was a central feature of Darwin's thought, because for him the 'struggle for existence' was an issue among individuals. But in 1962, Wynne-Edwards thoughtfully suggested that, in order to understand the evolution of social behavior, it is necessary to argue that groups, and not individuals, are the units of selection 7. The last addition to this debate was the formulation by Dawkins that genes themselves are the units of selection, while individuals are merely the temporary receptacles and vehicles for such genes 8.

In recent years, most of the debate on this question has been centered on the gene-versus-group as the unit of selection. An example of this is the recent didactic discussion on this topic by Sober 9. Somehow, the current terms of the debate already constitute a silent victory for the ultra-Darwinian view, which considers evolution as the external and visible manifestation of the differential survival of alternative replicators. The genes are the replicators and the organisms and groups of organisms are regarded as the vehicles in which replicators travel about. Thus, replicator selection is the process by which some replicators survive at the expense of other replicators, and vehicle selection is the process by which some vehicles are more successful than other vehicles in ensuring the survival of their replicators. According to Dawkins, the controversy about group selection versus individual selection is a controversy about two suggested kinds of vehicle, while the controversy about gene selection versus individual (or group) selection is a controversy about whether, when we refer to the unit of selection, we ought to mean a vehicle or a replicator 10. I think this is a very shrewd but fallacious argument, by means of which Dawkins has succeeded in reducing the individual organism to a mere appendix of the genome and thus, he has de facto reduced the debate to a conflict between genocentric versus socially-oriented conceptions of evolution. The dissolution of the individual organism into genes and proteins coded by such genes (which is the mindless outcome of molecular biology) has been introduced by Dawkins into the evolutionary discourse, thus harnessing in a quite indirect, if not overtly illegitimate

way, the *aura* of "hard" biological science that surrounds the endeavors of molecular biology, in order to support some contentions originally stated by biologists working in "softer" areas of biological research such as marine ecology or birds' ethology. Moreover, ultra-Darwinians feel very confident that they have won the day on the question of the unit of selection, as exemplified by the following quotation from a recent popular book:

Many people have seen the nature film in which droves of starving lemmings jump eagerly to a watery death as a resonant voice explains that when food becomes scarce, some lemmings sacrifice themselves so that there will be enough food for at least some of the group to survive. A few decades ago, such "group selection" explanations were taken seriously by professional biologists, but not now¹¹.

The previous quotation is in contrast to the following statement written in 1985 by a philosopher of science:

...The theory of natural selection tell us that, as a result of hereditary variation among the members of every species and of selection over this variation, every species *evolves*. The individual organism is of course the *immediate* (but perhaps not the sole) unit of selection...The crucial feature of the theory of natural selection is that the unit of evolution is the *species*; it is they that evolve¹².

Thus, the genocentric view has been identified by the media and most popularisers of science with the modern view on the question of evolution. On the other hand, molecular biology is currently under the limelight of biomedical research, and enjoys an avant-garde status, on which the practitioners of such a discipline relish themselves. Most molecular biologists are not directly concerned with evolutionary matters, and some subdisciplines such as molecular evolution are so vaguely defined as to encompass both studies of the structural transformations of specific molecules in time as well as studies which pretend to explain the whole biological evolutive process at the molecular level. It might be the case that the use of a 'genetic' jargon is the only and superficial link between ultra-Darwinism and molecular biology, but it seems that molecular biologists are not particularly interested in questioning the tenets of ultra-Darwinism, either because they ignore such tenets or they see no reason to challenge a line of thought that indirectly puts molecular biology at top of the biological disciplines.

Hereafter, I shall take at face value the claims of ultra-Darwinians which suggest that the gene itself is the unit of selection, and then I will develop an argument in order to show that there is nothing in molecular and cell biology that might support such a contention. I will not enter any

debate on whether the individual or the group is the true unit of selection; my only purpose is to demonstrate the basic incoherence of the ultra-Darwinian, genocentric view of evolution.

THE PROBLEMS OF THE GENE AS THE UNIT OF SELECTION

It is in the book The Extended Phenotype where Dawkins expounds his genocentric argument for the experts. In it, he defines a replicator as anything in the universe of which copies are made (this includes DNA and xeroxed sheets of paper). Next he subdivides replicators in active ones, i.e., those whose nature has some influence over their probability of being copied, and passive ones, i.e. those whose nature has no influence over its probability of being copied. Dawkins puts forward as an example of the first kind a DNA molecule which, via protein synthesis, exerts phenotypic effects that influence whether it is copied or not 13. Here we must notice that the ordering of factors in the previous argument already suggests that DNA is in full command, and the protein is treated as a sort of excrescence or passive manifestation of the information coded in the DNA. Here the protein is just a simpler version of the organism, considered as a vehicle or instrument for the successful propagation of the replicator (the DNA). But as Waddington was sharp enough to point out, a fundamental error present in the basic models of population genetics (which was the brewing tank for neo-Darwinian biology) is the oversimplification that attributes the coefficients of selection to the genes instead of the phenotypic traits 14. Other important biologists have clearly emphasized that natural selection acts directly on the organism's phenotype, but only indirectly on its genotype 15. The example, proposed by Waddington, that natural selection will select for survival and propagation those horses which run faster, thus escaping from predatory wolves, independently of whether such horses run faster because they have some genes which code for a "racing" function or because they were trained by an expert to do so, clearly illustrates the point that selection acts upon the phenotype and not upon the genes 16.

Ultra-Darwinians appear to neglect that the explanation of biological phenomena can be approached either from a synchronic or a diachronic viewpoint, depending on the nature of the phenomenon to be explained ¹⁷. The phenomenon of the sickling of red cells in sickle-cell anemia can be explained by considering the solubility properties of an abnormal form of hemoglobin which results from certain specific mutations in the gene that codes for the beta chain of hemoglobin (such mutations cause that the aminoacid glutamate is substituted by the aminoacid valine at position

six of the beta chain¹⁸). This synchronic explanation of the phenomenon does not require any historical consideration about the origin of such phenotypic character. On the other hand, according to standard evolutionary theory, the existence of particular forms of biological organization was not predictable in advance, because the "environment" that selects a given phenotype is not only constituted by the environment itself, but also by all the other phenotypes of the individual members of species that inhabit the region where selection is taking place. A phenotypic character artificially isolated from all others is not only selected for or against, it is also part of the "environment" for any other single phenotype that we might decide to isolate artificially. This is a complex many-bodied problem which results from the historical dimension introduced by the first appearance of self-replicating systems subjected to natural selection. This question requires a diachronic explanation which is very different from the explanations provided by molecular biology. Thus, the problem of the ultra-Darwinian position, as exemplified by Dawkins discourse, is that although molecular biology provides a powerful material basis for neo-Darwinism (as explicitly stated in Monod's book L'hasard et la nécessité 19), it does not in itself necessitate an evolutionary theory of any sort, because the explanations in molecular biology are synchronic in kind. Indeed, the explanations of the molecular phenomena studied by molecular biology, whether dynamic or structural, are compatible with any kind of evolutionary theory. If a demiurge had been directly responsible for creating each known past and present species, that would not affect our current explanations at the molecular level for protein folding, cell-signaling pathways, or the control of gene expression. If the existence of split-genes in eukaryotes was not the result of a certain evolutionary trend, but the consequence of a practical joke from God, that would make no difference as to our current knowledge of RNA self-splicing mechanisms that transform the lengthy primary transcripts into the shortened and mature versions which constitute messenger RNA.

A fundamental problem that needs to be faced by the genocentric view is that until now it has not been possible to obtain in the laboratory any evidence of the existence of non-enzymatic informational replicating systems. Current experience shows that one could not maintain a long polynucleotide sequence without informed enzymes, and one could not have informed enzymes without a long polynucleotide to code for them ²⁰. We are very much facing the old problem of what came first, the egg or the chicken. It is a fact that the overwhelming majority of terrestrial organisms use DNA as the primary genetic material and protein as the chief agent of catalytic function. However, it has been suggested that DNA-protein based life was preceded by RNA-based life, with RNA serving

as both the genetic material and main catalyst (Gilbert's RNA world ²¹). There are many uncertainties concerning how this RNA world arose. But a defining feature of the RNA world is that it must have contained RNA molecules that were capable of undergoing evolution based on natural selection. This requires that RNA (an informational molecule) is efficiently and accurately replicated in a reaction catalyzed by RNA itself 22. Several experts on the origin-of-life problem have serious doubts about the 'RNA first' notion. Particularly remarkable are the objections put forward by Gerald Joyce as a leading contributor to the field of self-catalytic RNAs and in vitro evolution. Joyce has stressed the obvious superiority of proteins over RNA in terms of catalytic power, as well as the unlikelihood of the prebiotic synthesis of RNA. Indeed, Joyce suggests that life did not start with RNA as a self-replicating molecule, but rather as a result of chemical evolution through non-instructed processes which allowed the chemical ordering of complex peptides, and possibly the formation of membranous vesicles. This stage made it easier for the later appearance of self-replicating molecular systems 23. Thus, a period of chemical non-genetic evolution was necessary so that a genetic system based on some simple RNA-like molecules was eventually able to arise.

The proponents of the RNA world agree that for Darwinian evolution to occur, RNA replication must be template-directed and energetically favorable, but the most crucial feature is that the RNA replicase must operate with sufficiently high fidelity to produce accurate copies of RNA molecules that are at least as long as the RNA itself. So far, the best candidate for an RNA-based RNA replicase is a ribozyme which contains 98 nucleotides but allows the propagation of an RNA containing only some 12 nucleotides ²⁴. The demonstration of an RNA enzyme with faithful replicase activity will put the previous existence of an RNA world on a firm basis, but researchers in this field agree that a process of Darwinian evolution would be required to develop such a molecule in the laboratory. Thus, the question would remain as to how Darwinian evolution could have begun in the first place ²⁵.

Some might be tempted to suggest that if the previous arguments do not support the idea that the gene itself (in this case an RNA gene) is the current unit of selection, it nevertheless was the original unit of selection upon which the original process of biotic evolution began. However, we must take into account the fact that RNA is quite a reactive and thus unstable polymer, unlikely to withstand truly prebiotic conditions ²⁶. All known ribozymes and coding RNAs need to be handled under the most gentle conditions in order to avoid their spontaneous breakdown. In order for an organized RNA to "survive" within the primeval soup, it was necessary that some organized structure was already in place so as to

protect such an early RNA from eventual degradation. Moreover, most experts on the question of the origin of life think that the shift between an RNA world and a DNA-based world should have occurred rather quickly during early biotic evolution ²⁷. DNA is a much more stable molecule than RNA, hence quite suitable for being the faithful storage of genetic information, a property that seems to be crucial for evolution based on natural selection; otherwise none of the phenotypic properties coded by the genetic material and selected by the environment would survive into the next generation ²⁸. But we must bear in mind that there is no evidence that DNA might replicate itself, which means that in the absence of specific proteins (DNA polymerases), there can be no further propagation of a specific DNA.

So far, molecular biology has only provided a single example of a truly autonomous replicator, and this happens to be not a nucleic acid but a protein: the PrP protein which constitutes the so-called prion, a cellular protein whose abnormal isoforms are apparently responsible for a number of chronic degenerative diseases of the central nervous system both in humans and animals 29. The normal isoform of the prion protein is the result of the normal expression and translation of the information coded by a DNA sequence (a gene). However, the abnormal isoforms are the result of an stochastic process by which a "seed" or "crystallization nucleus" formed by a few abnormally folded molecules of the PrP protein triggers a chain reaction which shifts the conformation of the normal molecules towards the abnormal configuration 30. Here, the relationship between the genotype and the phenotype with respect to this abnormal trait is completely stochastic. The presence of point mutations in the PrP gene that may facilitate the eventual appearance of abnormal isoforms of the protein can be traced in some extremely rare pedigrees which show an above-the-average incidence of some very rare neuropathies such as Creutzfeld-Jakob disease or Gerstmann-Sträussler-Scheinker disease 31. Because the resulting phenotype is not usually subjected to Mendelian inheritance, and hence it is basically unpredictable —being the result of a stochastic process of conformational change among proteins—there is no way for natural selection to select for or against such trait on a permanent basis.

Therefore, natural selection is able to "see" phenotypes, but the fixative or discarding effect of selection is possible only upon those traits of the phenotype that are stably coded in the genotype. This situation leads to the false impression that selection might be acting directly upon the genes, but we must bear in mind that any nucleotide sequence that is not expressed and eventually translated into protein, or that has no regulatory role upon the expression of other potentially expressed sequences, will

never be "seen" by natural selection and thus is liable to "drift" for as long as it has no phenotypic effect associated with it. The genotype is a coding device but its meaning is the phenotype; natural selection is only concerned with meaning, not with the actual coding or enciphering of such meaning.

ULTRA-DARWINIAN REPLICATORS CANNOT EXPLAIN THE EMERGENCE OF COMPLEXITY

From the ultra-Darwinian point of view, efficient replication is all that biology is about. Therefore, if there is a fundamental "goal" in biotic evolution, this should be the survival and spread of pieces of genetic information. The problem with this idea is that it has already been put to experimental test and the results are quite incompatible with the evident evolution of biotic complexity as we know it. Around 1967, a group led by Spiegelman set up an experiment in order to see what would happen to a basic replication system composed by an informational molecule (the short RNA containing the full genetic information for the bacterial phage Qβ), and the enzyme able to replicate such a molecule (the Qβ replicase, a protein enzyme coded by the aforementioned RNA) when the only constraint was directed to select those molecules that were able to replicate faster and produce more progeny (i.e., copies of themselves) in a test tube. We must bear in mind that the RNA and QB replicase molecules used in this experiment were obtained by purification from bacterial cultures infected with the QB phage, because the "life cycle" of such a "replicator" requires the participation of the whole metabolic machinery provided by the bacterial host cell in order to synthesize the replicase molecules which are eventually responsible of replicating the "replicator" (in this case the QB RNA). This illustrates that a gene (or a small genotype) cannot do very much in the absence of a phenotype (in this case, viral coded proteins), on which it depends for its own replication. The experiment consisted in incubating the $Q\beta$ RNA templates in the presence of ribonucleotides and the replicase, so as to produce further copies of the template. Then, after a certain incubation time, the resulting new templates were shifted to another test tube containing further ribonucleotides and replicase molecules. This procedure was repeated some seventy five times, but the time between transfers was gradually shortened in order to select those template molecules that were able to replicate faster and more efficiently. At the end of the experiment, the resulting templates corresponded to only 17 percent of the original Qβ genome's length. This was due to the fact that, as the experiment progressed, the original templates were gradually

replaced by shorter and shorter versions which were quicker to replicate. The final templates barely contained the nucleotide sequences which allowed the interaction between the replicase and the template for the further copying of such sequences. Of course, the resulting templates had lost any capability for coding a fully infectious phage particle, and as such were useless for the purpose of achieving the transfer and replication of their own information under natural conditions 32. This experiment of Darwinian evolution in vitro clearly shows that, in the absence of any simple phenotypic organization, an isolated "replicator" (in this case the RNA molecule) will "evolve" towards simplicity. This result is against the obvious fact that evolution on earth has gone from simplicity towards complexity. Recently, an example of continuous in vitro evolution of catalytic function has been reported. In this case a population of RNA molecules (ribozymes) that catalyze the template-directed ligation of RNA substrates was made to evolve in a continuous fashion. After approximately 300 successive rounds of catalysis and selective amplification during 52 hours, both the catalytic rate and the amplification rate of the RNAs improved as a consequence of mutations that accumulated along the evolution process. But in order to achieve this, it was necessary to perform 15 initial rounds of stepwise evolution in vitro, which requires intervention by the experimenter at successive steps of catalysis, selective amplification and mutation. Next, the resulting ribozymes were further subjected to 100 cycles of catalysis and selective amplification in the presence of added DNA primers, Moloney murine leukemia virus reverse transcriptase and T7 phage RNA polymerase which recognized a specific inbuilt promoter region present in the RNA substrates. The resulting advanced ribozymes were then subjected to 300 successive catalytic events in the presence of the aforementioned enzymes. The end result was a population of very efficient catalytic ribozymes which also exhibited exponential growth 33. It is a fact that the template-directed condensation of an oligonucleotide 3'-hydroxyl and ribozyme 5'-triphosphate, achieved by the ribozymes evolved in this study, is similar to the reaction catalyzed by an RNA replicase protein (the theoretically crucial enzyme for building an RNA world). However, this continuous evolution system can only be applied to reactions which involve the attachment of a promoter-containing substrate to a ribozyme that has a reactive group at the 5' end, and only if such a reactive group can be incorporated during transcription carried out by an added pre-existing enzyme, and the product of the RNA catalyzed reaction needs to be reverse-transcribed by a further pre-existing specific enzyme, in order to yield complementary DNA that contains the second strand of the promoter.

Therefore, it seems that an autonomous molecular replicator cannot go much farther, in evolutionary terms, in the absence of a manifold phenotype which can be "seen" and thus selected for or against by natural selection. The "vehicle" of ultra-Darwinian genes (the phenotype) appears to be the very crucial object speeding on the evolutionary runway. It is tempting to invert the terms of the ultra-Darwinians and thus to consider the gene not as the "driver" but as the "passenger" of the vehicle.

Another area of "hard" biological science which easily undermines the position of the ultra-Darwinians is the study of the evolution of metabolic pathways. The fact that metabolic pathways show an irreducible complexity, i.e., that they would not function if any single component were removed or altered without allowing for the appropriate modifications in the other components of the pathway involved, is a serious stumbling block for the idea that genes themselves are the units of selection. Biochemichal evidence suggests that metabolic pathways did not evolve by the sequential addition of steps to pathways that became functional only at the end. Thus, individual genetic loci coding for specific functions cannot be the subject of selection separated from the other loci coding for the other functions involved in a specific pathway. Natural selection must scan the full manifold phenotype in order to select the variants that will eventually survive; it cannot evaluate the survival of a single phenotypic trait in the absence of all the other traits that conform the organism 34. Moreover, such is the astonishing complexity of the molecular pathways involved in blood-clotting, the immune response and intracellular transport that some scientists doubt that they could have been built up as a purposeless matter of chance and necessity 35.

But perhaps the weakest point of the ultra-Darwinian position is that the gene as the unit of selection is incompatible with the evident evolution of biological complexity. The inconsistencies of the ultra-Darwinian position when trying to explain biological complexity can be illustrated by the following passage from the book *Evolution and Healing*:

Biologists today more or less universally believe that multicellular organisms ...arose from some group of the protozoa, in which each cell was a functionally independent individual. Most of their reproduction was asexual, with one cell dividing to form two new ones. In some modern protozoan species these two new individuals do not break completely apart but stick together in pairs. In others, the offspring of pairs stick together in filaments or sheets called colonies. In a few, colonies might differentiate into germ cells and somatic cells...This means that some previously independent cells, apparently voluntarily, give up reproduction and become genealogical dead ends. They devote themselves entirely to supplying nutrients and protection to the few germ cells that ultimately participate in sexual reproduction...Can this acceptance of a sterile, servile role be explained by natural selection? The answer is obviously

no , if this process means selection among cells for those best able to survive and reproduce. The answer is yes if the selection is among the genes best able to get themselves into future generations. If the reproductive and somatic cells of a *Volvox* colony have the same genes, it does not matter which cells do the reproducing and which become sterile...If colonies with ten reproductive cells and a hundred sterile ones reproduce more successfully than those with eleven and ninety nine, the tendency for most of the colony cells to assume a somatic service role will be perpetuated ³⁶.

Such a paragraph is part of the introduction to a chapter on the ultra-Darwinian explanation and solution for cancer. However, if organisms (or for the purpose of the present discussion, organized phenotypes), were only "vehicles" for guaranteeing the successful replication and survival of genes, then it must be the case that unicellulars are by far the most efficient and successful vehicles, and thus there would be no need for developing complex multicellular beings composed of different specialized cell types, which must be informed at all times of what the other cell types are doing, and whose genomes are subjected to very complex regulatory pathways that specify the expression of certain genes in certain cell types, but at the expense of continuously repressing the expression of most genes of a given genotype. It is a fact that typical unicellulars have at least 75 percent of their genes turned on at any time, while for a typical pluricellular, active gene expression does not amount to more than 4 percent of its coding genes at any given time in any particular tissue³⁷. Neither might one justify the existence of pluricellular beings on the basis that they represent "more successful vehicles" for genes than unicellular organisms. Unicellulars are the most universally distributed forms of life on Earth; they are found even under the Antarctic soil. Several kinds of unicellulars display universal distributions and some kinds of unicellulars prefer to survive under the most extreme conditions on Earth (extremophiles)38. Pluricellular beings are extremely fastidious in order to survive, their life cycles are lengthy and complex, and they require too many steps for achieving successful reproduction. Thus, the discrete presence of multicellular human beings in some Antarctic stations is not a justification for arguing that such humans are the "vehicles" which allowed the "conquest" by some genotypes of a further ecological niche to colonize.

CANCER CANNOT BE UNDERSTOOD IN ULTRA-DARWINIAN TERMS

Ultra-Darwinism cannot explain the phenomenon of cancer because such a phenomenon is a prime example that selection is acting at least at the level of the organism but not at the genetic level, as ultra-Darwinians think. Our main concern in relation to cancer is unchecked cell growth, proliferation and dissemination. A dysfunctional cell, sude as a non-acidproducing gastric cell, is not a cancer cell, even though it may have a mutated gene which explains why the cell is not producing hydrochloric acid. Molecular biology has established that most genes which code for proteins directly involved in the control of cell growth and proliferation in pluricellular organisms have their homologous counterparts in simple unicellular eukaryotes³⁹. Therefore, mutations in such genes are not enough to explain the loss of consistency between a tumor and its host. An organism must be able to regulate differences in specific cell activities; the control of cell growth and proliferation cannot be an exclusively internal cellular issue when the cell belongs to an organism. Cancer has a meaning only when it refers to an organism. Nowell has already suggested that the transition from normal to malignant cell carries with it the acquisition of inherent genetic instability 40. Moreover, there is important evidence that intrinsic cellular genetic instability precedes the development of cancer 41. Such an instability allows malignant cells to mutate at a higher rate than normal cells so that new variants are produced continuously. Many of these variants would be eliminated by metabolic or immunological mechanisms, but certain of these variants would possess selective growth advantages, and these clones would grow to dominate the tumor populations. Sequential selection over time leads to the emergence of sublines which would be increasingly abnormal both genetically and biologically 42. Benign tumors usually resemble their tissue of origin, but not every tissue component needs to be involved and the cells may or may not be in their normal relationship. Benign tumors arise in most tissues, increase in size but do not invade. They are usually separated from the surrounding normal tissue by a capsule of connective tissue. Specific tumor cells do not differ substantially from the structure of the normal organ cells. Malignant tumors, on the other hand, display two main characteristics: cellular abnormalities and invasion of the surrounding tissues. Tumor cells destroy and replace normal tissues; they also invade the blood and lymphatic vessels and thus they may be carried to other parts of the body and develop into secondary tumors (metastases) in distant sites. Malignant tumors have no well-defined capsule and the tumor cells grow in a much more disorganized fashion than is found in benign tumors 43.

Malignant tumors represent dynamic entities where there is a gradual acquisition of new characters as the tumor develops. This process is called tumor progression, and the general trend is for tumors to go from bad to worse, showing a movement towards a more aggressive behavior and an increase in their ability to invade. Not all cells in a single malignant tumor are identical; on the contrary, there is a range of populations of cells

expressing many different characters (phenotypes). Cells in a tumor may show differences in structure, morphology, growth rate, karyotype or behavior. This diversity is a consequence of tumor progression ⁴⁴. Studies based on individual markers in leukemias and lymphomas have shown that these cancers are monoclonal in origin (each and every one of these tumors descends from a single transformed cell). The situation with solid malignant tumors is less clear-cut and there is certain evidence to suggest that some carcinomas are multicellular in origin ⁴⁵. However, even if such tumors were monoclonal in origin, by the time they became clinically detectably there would have been tumor progression and the generation of diversity.

The more malignant the cells of a tumor are, the farthest the tumor will be from showing any degree of morphological organization. A cancer cell showing multiple mutations is more autonomous than the rest of the organism, but such a collection of mutations is not incompatible with cellular life. A cancer cell is wrong in relation to the rest of the organism, but it is right on its own. According to Canguilhem, we are able to label certain types and functions as normal only in reference to the dynamic polarity of life. Life is not passively subject to the environment, but it is also able to modify such an environment. Thus, life is able to establish and to modify the norms of its own activity. Therefore, the morbid state defines a kind of "normality" because it represents a certain relationship with the norms of life. The normality of the morbid state is different from physiological normality because it is related to a different set of norms 46. In this context, the abnormal is not equivalent to the absence of normality, because there can be no life in the absence of norms compatible with such a life. The morbid state is always a particular way of life.

Thus, it can be said that a cancer cell is normal in its own way, it performs its functions rather efficiently; moreover, it shows a growth advantage upon the so-called normal cells. A cancer cell is potentially immortal in cell culture, but also a cancer cell is somehow an entity in the process of leaving behind the organic plan. Organic order is a matter of control and restriction: tuning. Such a tuning cannot be strictly internal to the cell; it also depends on factors external to the cell. Cancer is incompatible, in the long term, with survival of the organism, but it is not incompatible, in the short term, with survival of the individual cell. The cancer state transforms a cell into a sort of parasite of the organism. The mutations in the genome of a cancer cell are not incompatible with cellular life; on the contrary, these mutations usually enhance the survival of such a cell as an independent being, but in the long term, the mutations reduce the survival of the cell (unless it is kept in a laboratory environment), because it ceases to be part of an organism. Cancer can only exist within an organism but not as an isolated cellular entity. The freer a cell is, the

less regulated it is. A high degree of regulation is only meaningful as long as the cell belongs to an organism.

If cancer were only a matter of random accumulation of mutations in certain genes involved in the control of cell growth and proliferation, then there would be no possibility for the organism to evolve, because the phenomenon of tumor progression gives the rather false impression that natural selection apparently favors cell proliferation over the survival of the organism. However, under normal circumstances natural selection must be acting upon the organism as a whole, not upon the genes or the cells as independent entities; otherwise, cancer would be a pathway for reversing the course of evolution because, in the example of cancer, the genome of the unicellular replicator—the genome of the dominant clone of cancer cells—is already different and more efficient than the genome of the original organism (the animal suffering from cancer) for the purpose of reproductive success: it leaves more copies of itself. Therefore, if selection were at the level of the genes, there would be no scope for organic development.

The substrate of a tumor is always changing; thus, it is not possible to establish the individuality of the tumor but only of one or another of its cells. Within a tumor the cellular individuality is enhanced at the expense of tissue organization. It is likely that most naturally occurring tumors are monoclonal in origin; however, as the tumor progresses it becomes a mass of homoeomerous (non-canonically structured) parts, each part defined by a clone of cells. One of such clones will seize tumor development until it is displaced and substituted by a further new clone. There is a great paradox behind the following facts: tumor cells show a great adaptability and autonomy in tissue culture; they are much less dependent on serum growth factors than their normal counterparts; many tumor cell lines show autocrine properties in culture; they can withstand wider variations in both pH and temperature of the culture medium without being affected in their growth and division rate, and tumor cells co-cultured with normal cells will always seize the culture and substitute the normal cells ⁴⁷. Tumor cells show an indefinite capacity for cell division (immortality in cell culture), whereas normal cells are subjected to the Hayflick limit, which establishes that a cell is programmed to produce a definite number of generations depending on the cell type; the limit for fibroblasts, the normal cells showing the largest potential for sequential cell division, is around fifty generations 48. Genes normally repressed in adult healthy cells are expressed in tumor cells, thus emphasizing the autonomy of tumor cells which do not respond to the normal mechanisms that coordinate and regulate gene expression within and among cells 49. The control of the cell cycle, on which coordinated cell growth and division depends,

is altered in tumor cells in such a way that the timing and progress of these cells' cycle becomes independent of the rest of the organism ⁵⁰. Therefore, tumor cells display phenotypes which distinguish them both from normal cells and from the rest of the organism.

It is obvious that a tumor cell phenotype is less complex than the phenotype of the whole organism where the tumor cell arose. Therefore, a tumor cell becomes a better case study for establishing whether natural selection is acting upon the genome or the individual. In this case, the individual is reduced to the explicit phenotype of the tumor cell. In ultra-Darwinian terms, the tumor cell is a better vehicle for the replication and spread of a given genotype (we must bear in mind that the genotype of an advanced tumor cell shows mutations and structural changes that make it clearly distinguishable from the original genotype of the organism) than the corresponding normal cell counterpart or the organism itself. Thus, if selection works for the most successful replicator, then it should be the case that natural examples of free-living tumor cells had already been discovered or were known, since a tumor cell constitutes a much better example of what Dawkins calls a germ-line replicator, which is potentially the ancestor of an indefinitely long line of descendant replicators, than any normal cell or germ-line cell of the organism 51. However, the fact is that there is no evidence of such free-living tumor cells, and the so-called immortality of these cells depends on the existence of independent and external complex phenotypes, represented by a devoted group of scientists around the world, responsible for feeding and caring for them.

The set of transformations that may occur within a tumor tend to enhance the individuality of the tumor cells: the cell showing the highest degree of dedifferentiation (anaplasia, which includes chromosomal instability or aneuploidy) and the fastest growth rate will prevail upon the rest of the tumor cells, thus giving origin to a new clone with new properties. Such a clone will compete with the previous cells for nutrients and space. Tumor progression is characterized by chaotic cycles of mass growth and destruction. However, phenomenologically speaking, a malignant tumor is meaningless because it cannot survive as a separate entity with defined morphology. Tumor cells cannot give origin to organized morphologies constituted by canonical parts. In fact, solid tumor growth leads to the production of aberrant masses known as spheroids, so poorly irrigated that the cells occupying the central regions of such spheroids become necrotic for lack of oxygen and nutrients 52. The toxic products released by such necrotic cells are often responsible for the demise of the organism suffering from cancer.

Actually, cancer can be understood as a conflict between an organized morphology constituted by canonical parts (the organism) and a part of

such a morphology that drifts towards an amorphous state. Tumor cells, cut down from their coordinated links to a nervous system, a cardiovascular system, a digestive and urinary apparatus, and so forth, are bound for destruction, because natural selection is obviously acting upon the whole organism, selecting for or against the whole set of phenotypic characters which define the organism as a whole living entity. The autonomous efficient replicator within the nucleus of the tumor cell cannot survive in the absence of a very complex organism which it was originally part of. Nevertheless, it would be rather silly to suggest that the complex organism constituted by canonical parts arose in order to act as a vehicle for the safe replication and spread of the genetic replicator. One cannot overemphasize that, if efficient genetic replication were the central biological game, then unicellular beings should have won the day. Taking ultra-Darwinism at face value leads to an absolute unintelligibility of biological complexity.

THE CONFLICTS BETWEEN MOLECULAR BIOLOGY AND NEO-DARWINISM

It might be the case that molecular and cell biology are really throwing some light on evolutive matters, but such light is casting deep shadows on most of the basic assumptions of neo-Darwinism (and hence on ultra-Darwinian tenets). For example, typological studies at the molecular level, based on the comparison of the aminoacid sequence of the cytocrome C protein among different classes of vertebrates, show that all terrestrial vertebrates are equally distant from fishes. There are no data in such sequences which might support the gradualist scheme: fish >> amphibian >> reptile >> mammal. Indeed, the amphibians, traditionally considered as intermediaries between the fishes and all other terrestrial vertebrates, are equally isolated from the fishes (from the molecular point of view) than any group of reptiles or mammals 53. The opossum, one of the oldest terrestrial mammals and widely regarded as a living fossil (it has remained unchanged since the late Cretacean period), has an aminoacid sequence for its hemoglobin that is very similar to the sequence in modern mammals, and equally distant, if not more, from similar protein sequences from amphibians and reptiles 54. In general, the molecular data based on comparison of protein sequences among groups and classes of species show that the members of a given taxon display the same degree of divergence when compared to members of groups external to such a taxon. On the other hand, very often the degree of morphological variation among species does not correlate with the degree of molecular divergence. For example, the degree of molecular variation among species of frogs (all of them having a very similar morphology) is equivalent to

the degree of molecular variation among mammals, in spite of the fact that mammals are morphologically quite diversified ⁵⁵.

Moreover, recent experiments carried out with bacteria in culture support a punctuated-equilibrium or saltationist model of evolution, in contrast with the standard gradualist view expounded by neo-Darwinism ⁵⁶. Besides, there is currently an intense debate about the molecular dating of the most recent common ancestor (cenancestor) of present-day organisms, since the molecular data locate such an ancestor not farther than two billion years ago. This means that since that date, there would not have been enough time for the evolution of biological diversity as we know it (from both the fossil and living record) if evolution was truly proceeding according to a gradual model 57. As if that was not enough, a recent report shows that guppies from the Caribbean can adapt to a new environment in just four years, a rate of change some 10 000 to 10 million times faster than the average rates determined from the fossil record. This result was obtained with real animals in a natural environment, not in the laboratory. This finding supports punctuated equilibrium over the gradualist view spoused by neo-Darwinians 58.

Differences in genome size among species bear little relationship to differences in number of coding sequences, and also show no direct correlation with organismic complexity (at least among pluricellular organisms). This is the famous C-value paradox 59. Because most of these differences are caused by variation in the number of copies of repetitive DNA sequences, discussions on the evolution of genome size have centered on the mechanisms that regulate the abundance of such sequences. This puzzling situation lead to the concept of "junk" or "selfish" DNA, because the largest proportion of DNA in eukaryotic genomes is never translated into protein. The apparent surplus of DNA may be to varying extents repetitive and meaningless in terms of the genetic code. Some is never transcribed into RNA, and other portions are transcribed into RNA but then spliced out before the RNA is translated into proteins. Either way such DNA is apparently without phenotypic consequences. Because of that, such DNA was viewed as a sort of harmless parasite that expands and replicates as long as it does not impair the function of the cell or organism 60. These facts were harnessed by ultra-Darwinians to support their contention that "junk" DNA was a prime example of the selfishness of the genes, which use the organisms as mere vehicles for their own propagation. However, now it seems that a lot of non-coding DNA is necessary for the efficient replication and expression of the coding sequences. Many noncoding sequences are directly involved in the control of gene expression both as promoters and enhancers of such expression 61. Introns, those non-coding sequences interspersed with the coding sequences (exons) in eukaryotic genes which are never translated into protein, are known to

be essential for the accurate and efficient transcription of eukaryotic genes. This is an empirical fact so well established by genetic engineers that cloned cDNA sequences coding for important proteins are artificially linked to heterologous introns within so-called gene expression vectors, in order to guarantee the successful transcription of this cDNA after the vector is introduced in a host cell that should act as a factory of cDNAderived transcripts and proteins 62. Our current knowledge of the higherorder structure within the cell nucleus suggests that an important part of non-coding DNA is directly involved in establishing and controlling such a structure, which is fundamental for nuclear physiology and seems to be specific at the cellular, tissue and species level 63. The nucleotype has been defined as those non-genic characters of the nuclear DNA that affect or control the phenotype, regardless of its encoded information. Any nucleotypic control of chromosome order will interact with genic control of chromosome function ⁶⁴. Based on experimental evidence, models have been proposed which suggest that modifications in the nucleotype might have serious consequences on the physiology of both the cell and the organism65. Moreover, the elimination of specific non-coding satellite DNA sequences has been associated with a clear reduction in fitness in the affected organisms 66. Therefore it seems that "junk" DNA after all is not as useless or selfish as it was formerly thought, and its presence is indirectly associated with phenotypic traits that can be "seen" by natural selection and thus selected for or against.

If there is a realm in which the correlation between genotype and phenotype is so close as to suggest that selection might be acting directly upon the genes and thus "non-distracted" by a cumbersome phenotype, is the realm of viruses. However, we must take into account that a viral replicator is nothing without a host cell where to replicate. There is not a single natural example of a virus that might replicate outside a cell. This implies that the virus, as an extreme parasite, must co-evolve with its host, and this last term means not only the cell but the whole organism to which the cell belongs. Usually, outbreaks of acute and lethal viral infections (such as Ebola virus outbreaks) reveal under close scrutiny that the unchecked viral replication is the result of infection in a species which is not the natural reservoir of the virus (most viral infections are asymptomatic when the virus infects its natural host ⁶⁷). Such infections cause the demise of the host organisms but at the same time work against the spread of the virus in nature. A virus that always kills its host is bound for extinction ⁶⁸. Some RNA viruses, such as retroviruses, have developed the strategy of integrating themselves as proviruses in the genomes of the host cells and thus, instead of being active replicators, they become "passengers" which are replicated along with the host-cell DNA, and as such are

vertically transmitted from mother to daughter cell ⁶⁹. I think it is impossible for ultra-Darwinians to reasonably suggest that in the case of retroviruses the host-cell (which belongs to an organism), is the mere vehicle for the spread of the provirus, which is nothing but a cluster of spurious genes, unessential for the host.

It is a fact that any selection negatively affecting the survival of the host will endanger the survival of the virus itself. Indeed, several kinds of viruses have evolved mechanisms so as to reduce the efficiency of the host immune response, not because they try to escape from immune-surveillance but because in many cases, as current evidence shows, an aggressive immune response is directly responsible for the pathogenesis of several viral infections, thus directly causing the demise of the host, and indirectly reducing the chances for the virus to replicate and leave further copies of itself. Therefore, a less dramatic immune response will protect both the host and the virus from early death or extinction 70. Moreover, in the case of the few retroviruses which are known to be active replicators, such as HIV 71, the rate of mutations, introduced in the viral genome during each round of replication, is the highest known among natural replication systems. This is due to the fact that the viral enzyme reverse transcriptase, which copies the viral genome, is extremely error-prone (about 10-3 substitutions per base 72). This results in the fact that patients that have been infected with HIV for some time display a large array of HIV strains or 'quasispecies', which can be isolated from their blood serum at different points in the course of infection. It is possible to isolate at the same time from the same patient but from different tissues two or more different quasispecies of $\overline{\text{HIV}}^{73}$. The genetic instability of viruses as $\overline{\text{HIV}}$ is such that current estimates suggest that the virus is constrained to reduce its actual replicative rate; otherwise it is bound for a quick extinction due to the collapse of its genetic information because of the large number of mutational errors 74.

Around 1883, August Weismann—who like Darwin, had been a believer in the inheritance of acquired characters in order to explain the source of variations that would make possible the process of evolution by natural selection—suddenly shifted to a fully anti-Lamarckian position, and thus he developed his concepts of the *germplasm*, which is that part of the organism that is potentially immortal, being handled from generation to generation, and the *somatoplasm*, which is that part of the organism that is mortal by necessity 75. The germplasm is the depository of biological inheritance, what we call today genetic information (the genes coded in DNA) while the somatoplasm can be identified with the body, or in current terms, the whole phenotype of the organism. Weismann specified the existence of a barrier between these two components of the organism, in such a way that it is possible to say (in contemporary terms) that informa-

tion might flow from the germplasm to the somatoplasm but not the other way round. Experiments carried out by Luria and Delbrück around 1943—which showed that mutations in cultured bacteria appeared in a spontaneous and random fashion, and that only those mutants which by chance adapted to the artificial conditions of selection introduced in the media (environment) by the experimenters were selected for survivalappeared to support in a clear, if rather indirect way, the existence of the original barrier suggested by Weismann 76. The eventual discovery of the structure of DNA in 1953 and of messenger RNA and the mechanisms for cellular protein synthesis in the early sixties of this century established the so-called central dogma of molecular biology, according to which information flows from DNA to RNA and then to protein, but not the other way round 77. However, such a "dogma" was already modified in 1970 with the discovery of the reverse transcriptase enzyme which transfers information from RNA into DNA 78. Nevertheless, the existence of Weismann's barrier was safely assumed, until in 1988 the first reports appeared suggesting that some mutations in typical bacteria were not as random as previously thought, and that there might be some scope for the organism (in this case a bacteria) to select the best sort of mutation that may result in an adapted phenotype to the specific conditions of the environment. Since then, a number of similar reports have been accumulating in the scientific literature, and although the issue has not been completely decided yet, it is possible to say that the assumed non-permeability of Weismann's barrier to the flow of information from the phenotype to the genotype is currently under close scrutiny 79. Of course, the eventual demonstration of rather direct information transfer from the phenotype to the genotype will completely eliminate the genocentric view from biological thought.

WHY NEO-DARWINISM CANNOT EXPLAIN ONTOGENESIS

Neo-Darwinians and ultra-Darwinians see evolution as the result of random mutations in DNA sequences mediated by natural selection, and consider that the processes of ontogenesis and epigenesis (the development of an organism with differentiated canonical parts from an undifferentiated fertilized egg), result form the expression of a program written in DNA, as if biological development were a simple matter of assembling the right sort of proteins. However, as we have discussed, DNA can only specify RNA and, with the help of regulatory networks, the time and place of RNA synthesis. But processes such as the self-organization of cell membranes, protein folding, and organelle and cell morphogenesis are dependent on some basic physico-chemical principles which have nothing

to do with the information encoded in DNA. There is compelling evidence that in adaptive complex systems, a great deal of order and structure emerge without having previously being built in the system⁸⁰. Many evolutionary biologist espouse a primitive notion of physical processes. For them, the flow of water can be explained on the basis of its molecular components, as if the equations of fluid dynamics were specified by the chemical elements of water and not by the whole behavior of the liquid. The following example illustrates that neo-Darwinian evolutionary biology is suffering from a syndrome of late 'atomism' that hinders our understanding of the really important issues in biology. If we try to understand the behavior of a mass of water by looking only at the water while it follows a course through a river, lake and a waterfall, we may conclude that such a flow is merely the random wanderings of water molecules, some of which accumulate, whereas others tend not to. Thus, as a consequence of this random jiggling plus selection based on the contingent factor of accumulation, the mass of water moves without any apparent purpose. However, if we also consider the landscape, things will look different, because the places where water accumulates are contingent on their surroundings, but once we know the surroundings it is possible to predict what will happen. Thus, water accumulates where the potential energy is lower, and this means it runs downhill. The geography of the surrounding landscape imparts a definite direction to the mass of water.

The random jiggling of water molecules is important because it actualizes a potential motion, but although the mechanism whereby individual molecules select where to accumulate is contingent, such a mechanism also acquires directionality from the landscape's geography (an individual molecule might eventually climb uphill, but the whole mass of water cannot). Thus, a truly modern view of evolution might boil down to the following: random mutations make phenotypes fluid enough to change, natural selection implements particular changes preferentially, but the overall result is more like water flowing through an invisible landscape made up by the nearby 'potential' phenotypes and constrained by the context, which is a mathematical 'phase space' that includes not only what actually happens, but what could have happened instead. For modern dynamical theories, the mathematical phase space is as real as the ordinary space, and it manifests itself by constraining the potential dynamics of a system into the behavior that we actually observe 81. In the case of biological evolution, there is a co-evolution of content (organisms) and context (the phase space), because the phase space itself evolves in response to the organisms that live in it, thus adding to the complexity of its study. In the same way, during the process of development the growing organism builds its own phase space along with its cellular structure. Both general biological evolution and individual development are constrained by the topology of phase space; thus, neither process is absolutely contingent 82 .

CODA

It is tempting to suggest that the different interpretations of the concept of unit of selection define a suitable topic for a case study in the sociology of science. Since the pioneering work of historians like Robert K. Merton and epistemologists like George Canguilhem, historians and philosophers of science cannot neglect the social circumstances which surround a particular event in the history of science. As Canguilhem suggested, the historical analysis of scientific theories should go from the concept towards the theory, because defining a concept amounts to formulating a problem, and formulating a problem requires the rational and ordered presence of a number of concepts which are not necessarily part of the theory that might solve the problem. Canguilhem notes that Oken (1779-1851) thinks of the organism as an organized society, but such a society corresponds to the concept of society according to the Romantic movement and is quite different form the society defined by the German Enlightenment (Aufklärung). Also, Canguilhem explicitly states that the history of the concept of cell cannot be dissociated from the history of the concept of individual being. Therefore, the development of the cell theory is colored by both social and emotional values 83. If such is the case, then why not to think that Darwin's concept of the individual as the unit of selection was very much in agreement with the outlook of a society in which individuals, classified according to class and gender, were actually struggling for survival in a world dominated by a capitalist empire (Victorian Britain). While the concept of the group as the unit of selection (put forward in 1962), agrees with the general trend in a world coming out from the ruins left by the Second World War, and subjected to the policy of nuclear fear that we knew as Cold War. Under such circumstances, individuals and nations grouped themselves in Eastern and Western blocks, as if realizing that a collective approach to defense and economic development was the best option for survival. Finally, in a post-modern world in which ideologies have been banished to the attic, and any discourse meant to justify a discipline or practice is subjected to the close scrutiny of 'deconstruction', which uncovers the 'essential' lack of meaning of such meta-narratives 84, we find ourselves facing the situation that the sources of wealth and capital have become 'corporations', abstract entities located in the virtual space of the internet, showing no specific loyalty to any nation or kind, and whose material assets can be shifted from one country to another at the push of a button. This trend towards 'non-locality' in some way mirrors the current physical understanding of quantum phenomena 85, and is part of a general anti-essentialist outlook which pervades this post-modern culture. In such circumstances the idea of the gene as the unit of selection and true object of evolution, reduces the manifold reality of the organism to an abstract, symbolic entity, the gene; and the 'struggle for survival' is displaced from the actual world where living beings either toil or rejoice, towards a literally no-man's land where symbolic constructions (genes) compete, reshuffle and replicate. If the human organism is nothing but the vehicle of a set of genes, then the Foucaltian disappearance of man—that modern invention—has been actually achieved ⁸⁶, and the door lays open for eliminating any ethical consideration regarding the fate of such non-essential entity.

And yet, it might be the case that behind the genocentric view of biology lies the paradoxical actualization of vitalism, understood (following Canguilhem) as the double negation of mechanistic physicalism and animism, the two metaphysical interpretations of the causes of organic phenomena; because vitalism is nothing more than the full awareness of the specific originality of living processes 87. Moreover, the modern concept of biological inheritance is linked to the concept of transmission of information, and for Canguilhem such a concept implies that there is a formula, a logos, written, preserved and transmitted. The genocentric view that pervades modern biology, implies a concept (or definition) of life as something inscribed on a material substrate (DNA or RNA), and this is equivalent to admit that there is an objective, material and formal definition of life. Therefore, the discovery of the chemical structure of the genetic material and the establishment of the genocentric view in biology, leads to the paradoxical confirmation of Aristotelianism in which the notion of form (morphe or logos) applied to the living organism implies that that such an organism is at the same time the concept of life 88. For Aristotle the nature of a living being is its soul, and this soul (anima) is at the same time the concept of the living. The soul is both the essence (ousia) and concept (logos) of life. Therefore, for Aristotle the concept of life is the living thing itself. But it is possible to argue further and thus to suggest that since for the German Idealism, life is the immediate unity between the concept and its nature (its reality), and therefore the concept cannot be recognized as distinct from such nature, then the modern outlook in biology might be closer to Hegel than to any other philosopher 89. On the other hand, a more pedestrian conclusion is that the genocentric view of evolution is a mere example of ideology in disguise, which might be suitable for a case study in the sociology of science, but otherwise has nothing to do with serious theoretical biology, as it is suggested by the fact that some of the founding fathers of molecular biology have never thought that Dawkins' ideas are really worth to worry about 90.

NOTES

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ABSTRACT

Since the enunciation of Darwin's theory of natural selection, the question of which one is the unit of natural selection has been debated both by biologists and by philosophers. The unit of selection is the concept of that 'something' to which biologists refer when they speak of an adaptation as being 'for the good of' something. The identification of individuals as the unit of selection was a central feature of Darwin's thought, because for him the 'struggle for existence' was an issue among individuals. But in 1962, Wynne-Edwards thoughtfully suggested that, in order to understand the evolution of social behavior, it is necessary to argue that groups, and not individuals, are the units of selection. The last addition to this debate was the formulation by Dawkins, in 1976, that genes themselves are the units of selection, while individuals are merely the temporary receptacles and vehicles for such genes. Somehow, the current terms of the a debate already constitute a silent victory for the ultra-Darwinian view, which considers evolution as the external and visible manifestation of the differential survival of alternative replicators. The genes are the replicators and the organisms and groups of organisms are regarded as the vehicles in which replicators travel about. The dissolution of the individual organism into genes and the proteins coded by such genes (which is the mindless outcome of molecular biology) has been introduced by Dawkins into the evolutionary discourse, thus harnessing, in a quite indirect way, the aura of "hard" biological science that surrounds molecular biology, in order to support some contentions originally stated by biologists working in "softer" areas of biological research.

Ultra-Darwinians appear to neglect that the explanation of biological phenomena can be approached either from a synchronic or a diachronic viewpoint, depending on the nature of the phenomenon to be explained. Thus, the basic problem of the ultra-Darwinian position, as exemplified by Dawkins discourse, is that although molecular biology provides a powerful material basis for neo-Darwinism (as explicitly stated in Monod's book L'hasard et la nécessité), it does not in itself necessitate an evolutionary theory of any sort, because the explanations in molecular biology are synchronic, while evolutionary biology needs diachronic explanations. Nevertheless, from the ultra-Darwinian view, efficient replication is all that biology is about. Therefore, if there is a basic "goal" in biotic evolution, this should be the survival and spread of pieces of genetic information. Here I develop an argument in order to show that there is nothing in molecular and cell biology that might support such a contention. In particular, I use the case of cancer to show that such a phenomenon is a prime example that natural selection is acting at least at the level of the organism but not at the genetic level, as ultra-Darwinians think. My central purpose is to show that the idea of the gene as the unit of selection is incompatible with the evident evolution of biological complexity.

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EL GENE COMO UNIDAD DE SELECCIÓN

Desde que se enunció la teoría de Darwin de la selección natural, tanto biólogos como filósofos han debatido sobre cuál es la unidad de selección natural. Unidad de selección es el concepto de ese "algo" al que se refieren los biólogos cuando dicen que una adaptación es "para el bien de" algo. Identificar a los individuos como la unidad de selección fue una característica fundamental del pensamiento de Darwin, porque para él la "lucha por la existencia" era un asunto entre individuos. Empero, en 1962, tras una cuidadosa consideración, Wynne-Edwards sugirió que, a fin de entender la evolución de la conducta social, es necesario proponer que los grupos, no los individuos, son las unidades de selección. El último agregado a este debate fue la propuesta de Dawkins, en 1976, de que los genes en sí son las unidades de selección, en tanto que los individuos son tan sólo receptáculos temporales y vehículos para dichos genes. De cierta manera, los términos actuales del mencionado debate representan ya una victoria silenciosa para la postura ultradarwinista, que considera a la evolución como la manifestación externa y visible de la supervivencia diferencial de replicadores alternativos. Los genes son los replicadores y se considera a los organismos y grupos de organismos los vehículos en los cuales viajan los replicadores. Dawkins introdujo en el discurso evolucionista la disolución del organismo individual en genes y en las proteínas codificadas por dichos genes (resultado inconsciente de la biología molecular), aprovechando de manera bastante indirecta el aura de ciencia biológica "dura" o "concreta" que rodea a la biología molecular, a fin de apoyar algunos argumentos propuestos originalmente por biólogos que trabajan en áreas más "blandas" de la investigación biológica.

Los ultradarwinistas parecen pasar por alto el hecho de que los fenómenos biológicos pueden explicarse tanto desde un punto de vista sincrónico como de uno diacrónico, según la naturaleza del fenómeno por explicar. Así pues, el problema básico de la postura ultradarwinista, ejemplificada por el discurso de Dawkins, es que si bien la biología molecular brinda una poderosa base material para el neodarwinismo (como se afirma explícitamente en el libro de Monod L'hasard et la nécessité), no requiere en sí misma de una teoría evolucionista de ningún tipo, ya que las explicaciones de la biología molecular son sincrónicas, en tanto que la biología evolucionista necesita explicaciones diacrónicas. Sin embargo, desde la perspectiva ultradarwinista, la biología consiste tan sólo en una replicación eficiente. Por consiguiente, si existiera un "objetivo" básico en la evolución biótica, éste sería la supervivencia y diseminación de fragmentos de información genética. Aquí desarrollo un argumento para demostrar que no existe nada en la biología molecular y celular que pueda apoyar semejante argumento. En particular, recurro al cáncer para señalar que tal fenómeno es un ejemplo claro de que la selección natural está actuando cuando menos al nivel del organismo pero no a nivel genético, como piensan los ultradarwinistas. Mi objetivo central es demostrar que la idea del gene, como unidad de selección, es incompatible con la evidente evolución de la complejidad biológica.

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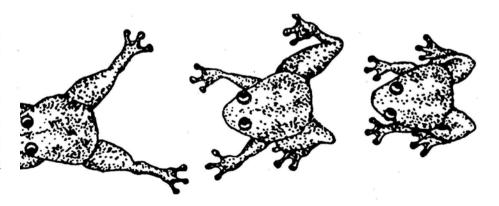
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