THE DIFFICULT THOUGH ESSENTIAL DIALOGUE BETWEEN BIOLOGY AND ITS PHILOSOPHY

Luis Marone, Fernando A. Milesi, Rafael González del Solar, Eduardo Tomás Mezquida, Javier López de Casenave and Víctor R. Cueto

SUMMARY

Charges leveled against Evolutionary Theory by Natural Selection (ETNS) of not being falsifiable are not adequately answered, not to mention dispelled, by exhibiting any amount of empirical evidence. Immunity to falsification means that ETNS can assimilate any possible data as a favorable case, and therefore empirical evidence cannot affect ETNS's truth value. As a consequence, any attempt to provide an answer to such charges can only dwell at a philosophical level of analysis, whereas assessing the quality and quantity of the evidence supporting ETNS (whether such evidence comes from systematics, ecology, ethology, physiology or molecular genetics) belongs in the scientific level. Since ETNS is a central element for the intelligibility of biological science, it is of fundamental importance to pay attention to the philosophical arguments that counsel to mitigate the role of falsifiability as a criterion for good science. The relevant criteria should take into account both that factual theories need empirical content and that historical disciplines should be part of science. The consequences of those arguments for research practice in evolutionary ecology were previously assessed (Marone et al.*, 2002). Sadly, our attempt was misunderstood by Néspolo (2003), who construed it as an attack to evolutionary theory. In the present paper we briefly review both mentioned papers, attempt to further analyze the consequences of ETNS being a premise of ecological research, and conclude by suggesting that evolutionary biology would benefit, as every scientific discipline, from a more fluid dialogue between science and its philosophy.*

RESUMEN

La acusación que la Teoría de Evolución por Selección Natural (TESN) es irrefutable y que, por lo tanto no es científica, no puede resolverse presentando evidencia a su favor. La crítica indica que cualquier resultado estará a su favor y que, por ello, la evidencia no afecta su grado de verdad. La respuesta puede buscarse solo a nivel epistemológico, mientras que el análisis de la calidad y cantidad de la evidencia en favor de la TESN, provenga ella de la sistemática, la ecología, la etología, la fisiología o la genética molecular, pertenece al ámbito metodológico o científico. Como la TESN es el elemento central que aporta inteligibilidad a la biología, la reflexión filosófica sugiere la necesidad de reemplazar el requisito de refutabilidad como criterio único de "buena ciencia" por un criterio matizado, más amplio e igualmente riguroso, que atienda tanto la necesidad de que las teorías científicas tengan contenido empírico como la de aceptar y apreciar a las disciplinas históricas en el corpus *de la ciencia. Las consecuencias de esos razonamientos para la práctica de la investigación ecológica fueron analizadas anteriormente (Marone* et al.*, 2002), pero el intento no parece haber sido comprendido por Néspolo (2003), quien lo tomó como un ataque a la TESN. Aquí se revisan los argumentos de los artículos mencionados, profundizando el análisis de las consecuencias de que la TESN sea una premisa de la investigación ecológica y se sugiere que la biología evolutiva se beneficiaría de un diálogo más fluido entre la ciencia y la filosofía.*

Although a great deal of ecological research assumes Evolutionary Theory by Natural Selection (ETNS) as being true (i.e., that ETNS is part of ecology's theoretical framework), ecologists do not always realize that unexpected results on adaptations are potentially falsifying evidence for ETNS. Marone *et al*. (2002) reviewed some of their own previous results on desert bird ecology to show that results suggesting lack of adaptation are commonly recorded, and that this fact should be a source of reflection for the discipline of evolutionary biology. A short time later, Néspolo (2003) accused Marone *et al*. (2002) of using "naïve and qualitative evidence" to conclude that ETNS "is obsolete", and considered that there is currently more evidence supporting ETNS than ever before. We do not think that ETNS is obsolete at all, but initially deemed it futile to add more pages to the already abundant, and sometimes redundant, discussion on

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Luis Marone. Biologist. Universidad Nacional de La Plata, Argentina. Doctor in Biological Sciences. Universidad Nacional de San Luis, Argentina. Professor, Universidad Nacional de Cuyo, Argentina. Researcher, CONICET, Argentina. Fellow, Center for Advanced Studies in Ecology and Biodiversity, Pontificia Universidad Católica, Chile. Address: IADIZA, Casilla de Correo 507, 5500 Mendoza, Argentina. e-mail: lmarone@lanet.com.ar

Fernando A. Milesi. Biologist. Universidad de Buenos Aires (UBA), Argentina. Research Assistant, School of Biological Sciences, University of Southampton, UK. Doctoral student, UBA, Argentina.

Rafael González del Solar. Biologist. Universidad Nacional de Córdoba, Argentina. Fellow, Fundación Carolina, Universitat Autònoma de Barcelona, Spain.

Eduardo Tomás Mezquida. Doctor in Biology. Universidad Autónoma de Madrid. Spain. Postdoctoral Associate, Department of Zoology and Physiology, University of Wyoming, Laramie, USA.

Javier López de Casenave. Biologist and Doctor in Biological Sciences, UBA, Argentina. Profesor, UBA, Argentina. Researcher, CONICET, Argentina.

Víctor R. Cueto. Biologist and Doctor in Biological Sciences, UBA, Argentina. Professor, Universidad de Buenos Aires, Argentina. Researcher, CONICET, Argentina.

RESUMO

A acusação que a Teoria de Evolução por Seleção Natural (TESN) é irrefutável e que, portanto não é científica, não pode se resolver apresentando evidência a seu favor. A crítica indica que qualquer resultado estará a seu favor e que, por isto, a evidência não afeta seu grau de verdade. A resposta pode buscar-se somente a nível epistemológico, enquanto que a análise da qualidade e quantidade da evidência em favor da TESN, provenha ela da sistemática, a ecologia, a etologia, a fisiologia ou a genética molecular, pertence ao âmbito metodológico ou científico. Como a TESN é o elemento central que aporta inteligibilidade a biologia, a reflexão filosófica sugere a necessidade de substituir o requisito de refutabilidade como critério único de "boa ciência" por un critério matizado, mais amplo e igualmente rigoroso, que atenda tanto a necessidade de que as teorias científicas tenham conteúdo empírico como a de aceitar e apreciar as disciplinas históricas no corpus *da ciência. As conseqüências de esses posicionamentos para a prática da investigação ecológica foram analisadas anteriormente (Marone* et al.*, 2002), mas a tentativa não parece haver sido compreendida por Néspolo (2003), quem considerou como um ataque a TESN. Aquí se revisam os argumentos dos artigos mencionados, profundizando a análise das conseqüências de que a TESN seja uma premissa da investigação ecológica e se sugere que a biologia evolutiva se beneficiaria de um diálogo mais fluido entre a ciência e a filosofia.*

ETNS and the concept of adaptation. Yet, Néspolo and his collaborators (see Artacho *et al*., 2005) have insisted on the key role empirical evidence would have in discrediting arguments like ours, and a reply to Néspolo (2003) is now highly appropriate. The main reason is that such a reply would show, especially to young biologists and students, that the assessment of scientific theories deserves both epistemological and scientific attention. Herein, two theses shall be defended: 1) philosophical analyses are supplementary to scientific ones in the evaluation of evolutionary theory, and 2) evolutionary researchers would benefit from a more fluid dialogue between science and its philosophy.

Scientists are used to discussing about the best type of evidence that should be employed in testing scientific theories. Such debates may dwell on whether that evidence should arise from experiment or observation, be qualitative or quantitative, be based on statistical hypothesis testing or not, and so on. These are fundamental methodological topics that are usually approached at a scientific level of analysis, i.e., a scale that presupposes a number of philosophical views, which are not analyzed. Philosophers of science, on the other hand, investigate precisely those philosophical assumptions (e.g., which are the requirements for a theory being considered scientific) lying beneath the very attempt of doing science. Inquiries of this sort constitute a step logically prior to any debate on the adequacy, quality, and quantity of the results obtained in scientific practice. This is so because it is at the philosophical level of analysis that epistemic values guiding scientific research are unearthed (or proposed), analyzed and established.

The point in the previous paragraph can be illustrated with an example. Imagine that an astrologist "predicts" (in fact "prophesizes") that individuals belonging to Aries will get a job next Tuesday, and that some *researchers* record that all the jobs offered that Tuesday were gotten by Aries people. Those researchers might be tempted to reach the conclusion that the astrological "prediction" has been confirmed on the base of positive empirical evidence. Genuine *scientists*, however, will doubt or deny the value of such confirmation despite the evidence seemingly supporting astrology. [Here we have made use of the distinction between *research* and *science*, put forth by Marcelino Cereijido (1994, 1996) in order to distinguish those people who conduct research without worrying about the philosophical and sociological aspects of their activity (*researchers*) from those who conduct research while being deeply aware of those assumptions (*scientists*); the latter conduct "science with brains" (*ciencia con seso*; Cereijido, 1994) or "epistemologically informed science" (*ciencia epistemológicamente culta*; Marone and González del Solar, 2005)]. But, back to the example, are the *scientists* being arbitrary? Not at all, if they provide good reasons for their skepticism. They could point out, for instance, that astrological explanations are not genuinely scientific, since they either appeal to supernatural entities (i.e., they violate the philosophical assumption of scientific *materialism*) or contradict some consequences of well confirmed scientific theories (i.e., astrological statements have scarce or nil *external consistency*; Bunge, 2000). [The reader should not be deceived by the appearance of closeness or authoritarianism of this characterization. Scientific knowledge is indeed changeable: either unfavorable data or new hypotheses may challenge some portions of the established knowledge. However, such *newcomers* must prove their worth both on rational and empirical grounds, and at least have the support of some general scientific theory]. Before gathering or assessing any kind of results, scientists may well be skeptic about a doctrine claimed to be "scientific" because science, besides being grounded on its method, is founded on a set of philosophical assumptions that have to be met.

In sum, the overall assessment of a factual theory involves decisions about its scientific status (Does the theory constitute genuine scientific knowledge?) as well as its truth value (Does it offer predictions that coincide with some specific data?). The first question leads to specify some "demarcation criteria" that distinguishes science from non-science. The acceptance or rejection of those criteria *is logically prior* to decisions made at a scientific level of analysis, i.e., decisions guided by the second question, such as those concerning the degree of complexity of the mathematics utilized for deducing quantitative predictions, the adequacy of experimental designs or the rigor of statistical tests. Controversies on the criteria for recognizing good science, or good theories, have kept busy a number of scientists and philosophers of science for a long time (Popper, 1985; Sokal and Bricmont, 1999; Chalmers, 2000). They debate, for example, whether theories should deal only with natural entities, generate predictions that make them falsifiable (i.e., vulnerable to possible counterexamples), contribute explanations consistent with the bulk of established knowledge or include specific causal mechanisms in their arguments. The reflections proposed in Marone *et al*. (2002) belong in this philosophical level of analysis.

Néspolo (2003) offered his review to biology students and young biologists, a pedagogical goal that inspired both our original essay and the present one: the aim is to provide those students and young biologists with further elements, philosophical as well as scientific, for assessing some of the reasons and consequences at stake in the current debate on the status of ETNS. And we also aim at showing the usefulness of becoming acquainted with at least some issues on the philosophy of biological science. But now, the original arguments should be reviewed.

Previous Assertions

Marone *et al*. (2002) stated that ETNS is often, though many times tacitly, asserted as a premise of ecological research. In those cases, ETNS is articulated with other hypotheses and data in order to deduce predictions, which constitute one of the basic tools for testing ecological hypotheses, the other one being empirical evidence. By being one of the components of its theoretical framework, ETNS affects ecological research transferring to it some of its reaches and limits. A consequence of this is the contrast between the rather satisfactory explanative power of evolutionary ecology and its relatively low predictive power.

ETNS has been criticized from a number of scientific and philosophical quarters. Most of the attacks have been duly dispelled by now, and most biologists accept the general terms of the theory (Ruse, 1979). However, research in evolutionary ecology sometimes involves a contradiction. A major criterion that determines the degree of attention paid to a theory by the community of ecologists or the chances of projects being approved is whether they provide or use falsifiable hypotheses or predictions (Agrawal, 2004; Harte, 2004). Such a demanding requisite, however, seems to be abandoned when assessing ETNS itself or its ecological consequences. The philosophical school originated in the works of the Austrian-English philosopher Karl Popper (1902–1994), namely *critical rationalism* or *falsificationism*, states that scientific hypotheses or theories are characterized by being falsifiable, and that evolutionary theory would not be scientific since it is incapable of providing bold, risky predictions (Popper, 1985). In other words, given that evolutionary theory does not exclude from its explanatory power any possible case (i.e., it has low empirical content) empirical evidence is unable to affect its (known) truth value (Peters, 1991). Well then, is this philosophical critique valid? Is ETNS non scientific? ETNS could overcome that attack if, in finding evidence that cannot be accommodated (without recourse to *ad hoc* assumptions) to relevant predictions, biologists decided to falsify the theory (i.e., if biologists treated the theory as a scientific hypothesis, and not as a philosophical one.) Within this context, Marone *et al*. (2002) reviewed some studies in their research program on community ecology of desert birds in order to assess their behavior regarding ETNS (and invited colleagues to do the same thing!). In each case, plausible selective pressures (for instance, that nestlings would suffer high predation rates, that soil seeds would be heterogeneously distributed, and that seed size would vary among plant species) were postulated and measured. Results were deemed to indicate important selective pressures, so ETNS and other ecological statements were used to generate predictions on adaptations (e.g., that particular birds would select nesting sites subject to lower predation rates and feeding sites with high seed availability, and that particular birds would exhibit a tight relation between beak morphology and the size of the seeds they consumed and preferred). Finally, those predictions were put to test by means of observations or experiments (see details in Cueto *et al*., 2001; López de Casenave, 2001; Mezquida and Marone, 2001, 2002; Marone *et al*. 2002, 2004; Mezquida 2004). None of the expected adaptations was found and the authors asked themselves whether they were ready to abandon ETNS as a premise of ecological research. The answer was, of course, a solid negative. (This part of the paper should have been read by Néspolo (2003) before accusing the authors of considering ETNS obsolete). Was this behavior non critical or not scientific enough? That was not what we thought because there are good epistemological reasons to keep ETNS (at least) as an essential tool for ecological research. The main reason is that, as the *only* criterion for good science (or theories), falsifiability is neither epistemologically nor methodologically justified. The basis for this assertion has been debated many times in the philosophical literature, and Marone *et al*. (2002) offered a summary of the most important points: a) testing a hypothesis is a matter very different from testing a theory, not to mention a system of theories such as ETNS; b) whole, complex theories cannot be falsified because the possibility is always present of appealing to *ad hoc* hypotheses that explain the failure of predictions; c) *ad hoc* hypotheses are unavoidable, since we scientists are exposed to make both Type I and Type II errors; d) *ad hoc* hypotheses should be acceptable as long as they are put forth *bona fide* and are independently testable. As a consequence, a set of more flexible, and realistic, criteria for characterizing good science, in particular theories, would do a better job.

Néspolo (2003), in turn, asserted that the modern theory of evolution (an expression that he used apparently with the same meaning of ETNS) is one of the most pervasive theories in the biological sciences, with natural selection as the main mechanism explaining adaptation. There is, however, a confrontation between two different ways of approaching, and teaching, the theory: the systematic–taxonomic–historical approach and the perspective offered by evolutionary genetics. The former approach prevails in the "Chilean style of teaching evolution", particularly in the undergraduate courses of some major Chilean universities. There, natural selection and phenotypic variation are only mentioned from Darwin's words directly, or from anecdotic and qualitative examples instead of being taught along with the well-established quantitative tools developed to measure them. The proofs for natural selection or evolution itself, Néspolo (2003) goes on, are not usually taught to Chilean undergraduates. The weaknesses of this teaching approach have provoked a general problem of ignorance, which has served the attacks for suppressing the teaching of evolution. Given that "empirical evidence is the most important structural support for any hypothesis that is posed to become a theory" (Néspolo, 2003) and that such evidence is not systematically taught at the university, the author offers a short but representative review of the recent evidence for natural selection from the perspective of quantitative genetics and phenotypic selection.

A Dialogue between Science and its Philosophy?

Perhaps because of his enthusiasm in defending evolutionary theory, Néspolo erroneously attributed to Marone *et al*. (2002) the assertions that "...it is impossible to measure natural selection..." and that "evolutionary theory is obsolete because it does not explain ... apparently non-adaptive behavior" (Néspolo, 2003). Letting aside the fact that Marone *et al*. (2002) did not state or imply any such ideas, they can be used here to clarify their point. Many proponents of falsificationism think that natural selection can be measured, but they also think that measurements do not affect the truth value of the theory. As it has been explained above, the problem is not that the theory lacks predictions but that it predicts *everything*. This philosophical subtlety allows us to appreciate the differences between a philosophical assessment (the one attempted by Marone *et al*., 2002) and a scientific appraisal (that was performed by Néspolo, 2003). Let us analyze the role that each kind of reflection plays in the construction of confident knowledge.

When Marone *et al*. (2002) reviewed some of the results in their research project they did not have in mind an examination of whether those results reject ETNS: "… el número y variedad de enfoques de nuestros estudios no proveen de manera alguna una muestra adecuada para decidir sobre el grado de verdad de la TESN..." ["… the number and variety of approaches of our studies in no way provide an adequate sample for deciding on ETNS's degree of truth..."]. Their motivation was instead to inspect our own ideas regarding the tension between unexpected empirical results and the status of ETNS. From such inspection certain reflections arose that are now offered, together with some additional comments, to the community of evolutionary biologists.

1- Regarding the research project on desert bird communities reported in Marone *et al.* (2002), there were several cases in which predicted adaptations were not found. Some examples were provided and other colleagues invited to contribute their own, whether published or not, to be used during the teaching of ETNS to young biologists.

As Néspolo (2003) rightly noted, "non-adaptive processes are common place in nature". Examples like ours may well be useful in order to introduce some nuances into the implications of the information carefully reviewed in Néspolo's tables 1-4, providing a more realistic view of the kind of results that evolutionary biologists frequently find. Such a conceptual move would have, among other positive consequences, an important pedagogical role, contributing to present science as a dynamic enterprise, full of subtleties and controversy, and not as a frozen doctrine (González del Solar and Marone, 2001).

2- In spite of not having found evidence for the expected adaptations, Marone *et al.* (2002) did not feel prone to resign ETNS as a part of the theoretical framework of their ecological research program without deepening the analysis of the demarcation criterion offered by falsificationism.

This attitude corresponds with that condemned by falsificationism. Immunity to counterexamples drove Popper (1985) to deem that theories such as Marxist historicism or Freudian psychoanalysis are not to be counted among scientific theories. In Popper's view, those theories cannot be empirically wrong because they are too flexible, and can assimilate any possible outcome of empirical tests. Contrariwise, Popper argues, General Relativity Theory (GRT) was effectively at risk when in 1919, during an eclipse, Eddington made the observation that light rays curved when approached by the sun. According to Popper, GRT is falsifiable because it is not compatible with contradictory empirical evidence: had the light rays not curved the theory would have had to be abandoned. In this view a theory is scientific (falsifiable) if it is genuinely at risk when tested against empirical evidence because some observation statement exists that is at once logically possible and incompatible with such a theory (Chalmers, 2000). In short, when the theory is vulnerable to counterexamples. Given that ETNS would not be falsifiable (i.e., the theory would not exclude any possible result from its explanatory power) the degree of truth of ETNS could not be approached by weighing favorable *versus* non favorable data the way Néspolo (2003) seems to believe appropriate, simply because counterexamples are not possible (Peters, 1991). So, do we abandon ETNS or do we look for other criteria to describe good science?

3- Just like it occurs in other scientific disciplines, evolutionary ecologists are readier to modify the periphery of assumptions affecting the testing of ecological hypothesis than to resign ETNS.

Popper (1985) maintained that the use of *ad hoc* hypotheses was not legitimate, but only a tool for salvaging theories otherwise condemned to falsification. And it must be admitted that Popper did not lack a point. Indeed, if our theories are immune to non favorable empirical data, then what are the roles of prediction and observation in science? Popper provided interesting examples for justifying his worries about *ad hoc* hypotheses. However, there are clear counterexamples as well, one of the most widely known being that of the Newtonian Gravitation Theory, which in a Popperian view should have been falsified (according to the astronomical knowledge of the mid nineteenth century) due to anomalies in the orbit of Uranus (Klimovsky, 1995; Chalmers, 2000). Astronomers John Adams and Urbain Leverrier, each on his own, decided to modify *ad hoc* some data presupposed by celestial mechanics in order for them to fit the predictions of Newtonian physics. Adams and Leverrier put forward that the anomalies between the predictions of Newtonian mechanics and the observed orbit of Uranus were due to the existence of a not yet observed planet, which would have to have a certain mass, and be in a particular region of the skies. The existence of such a planet (Neptune) was confirmed some time later through telescopic observations. Thus, Newtonian theory survived the threat posed by the said anomaly because Adams and Leverrier did not deem it to be falsified even though unfavorable data were available. And because Neptune happened to exist! Had the planet not been there, the alternatives would have been to introduce some other *ad hoc* modification into the periphery of the test or deem Newtonian theory falsified and abandon it. We ecologists behave similarly with regard to predictions on adaptations. When we do not find data favorable to those predictions, we readily modify the periphery of assumptions, substituting a new hypothesis of a similar kind for the original auxiliary one thought to be problematic. For instance, regarding one of the cases presented in Marone *et al.*, 2002, an association between nest location and high nest predation rates, a result contrary to the one predicted, might be explained by the existence of important physical constraints that determine the places for nest building in spite of nest predation risk. This attitude is now understood and justified by up to date philosophy of science, especially when the new *ad hoc* hypothesis is put forth *bona fide* (Bunge, 2000), and to the extent that such a hypothesis is empirically testable (Lakatos, 1974; Bunge, 2000; Chalmers, 2000).

4- In the face of such a state of affairs, some other criterion or criteria are needed for good science while conducting (and judging) research.

This epistemological problem constituted the central axis in the article by Marone *et al.* (2002). The authors suggested Bunge's scientific realism as a useful approach to it, since Bunge's view provides a *system* of criteria for good science that is flexible and rigorous at the same time (Mahner, 2001; Bunge, 2002, 2004). Bunge's system is preferable to naïve falsificationism, among other advantages, because it makes room in the realm of science for those disciplines that deal with complex realities, multiple causation, and interaction among causal mechanisms; sciences studying highly variable systems subject to contingency (Marone *et al.*, 2002, Marone, 2006). However, there are other epistemological views that may, and should, be taken into account when reflecting on the philosophical problems posed by scientific practice. Useful introductions to many such problems can be found in textbooks especially written for scientists (e.g., Hempel, 1995; Klimovsky, 1995; Chalmers, 2000).

5- It is necessary to double research efforts in those areas of ecology that use ETNS as a premise, seeking to enhance its predictive power. In order to do so it is necessary to conduct interdisciplinary biological research.

The main conclusion of Marone *et al*. (2002) was that we need a system of criteria for good science, sufficiently flexible and rigorous at the same time, to judge ETNS. The paper, however, did not issue an invitation for remaining crossed arms in the face of the current low predictive power of ETNS. The falsifiability criterion, combined with other ones, should continue to be one of the criteria utilized by evolutionary ecologists. The conceptual move proposed should not be viewed as an opportunity to merely salvage ETNS, but rather as an opportunity to reflect on our metascientific views, widening them in order to conduct better science. ETNS should not be taken as a metaphysical assumption of ecological research, like those of the existence of reality or its (limited) knowability. To take ETNS as an immutable principle, totally invulnerable to unfavorable empirical evidence would make little service to ecological research, and to ETNS itself. On the contrary, the use of a system of criteria for good science is only a step in the hard road that may lead to find (i.e., imagine and test) biological laws, still to be discovered, that might be the basis for enhancing ETNS's predictive power. Such an effort should be better made by using an interdisciplinary biological approach, and should involve epistemological (e.g., what are the more adequate criteria for good science?) as well as scientific decisions (e.g., what is the status of the theory in the light of current evidence?), which need a fruitful dialogue between science and philosophy.

Concluding Remarks

Scientists and philosophers frequently see each other with little sympathy. This is due, in part, to a lack of understanding of the role and relevance of each other's task for advancing human knowledge. Our analyses are not related with the amount of empirical evidence favorable to ETNS, but with the importance of (frequently implicit) criteria for deciding what the role of empirical evidence should be with regard to the testing of hypotheses and theories. We wished to highlight the need for evolutionary biologists to be aware of the criteria they are using for recognizing what is and what is not good science. Even when such criteria are not explicitly stated and justified, they are present all the same, presupposed by the particular way in which the scientist conducts research. We believe that the scientific status of ETNS must be founded on criteria broader than those offered by the doctrine of falsificationism, but we also believe that ETNS needs to be continuously revisited in order to develop new biological laws with the maximum predictive capacity permitted by the kind of reality studied by evolutionary biologists. ETNS is the best theory currently available for inspiring research programs on adaptation in ecology, but just like any other scientific theory, it is malleable human knowledge (González del Solar and Marone, 2001). Needless to say, this conclusion is not to be construed as supporting doctrines that attempt to understand natural systems or their changes in non scientific manners (e.g., creationism) or from a relativistic standpoint (e.g., different postmodern strains). Our emphatic invitation to avoid dogmatisms of any kind starts in some naturalistic (i.e., materialistic) and ratio-empiricist philosophical assumptions leaving no room for the merciful acts of a divinity or to the impossibility of rationally advancing scientific knowledge.

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