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**Three Billion Years of Research and Development.**

As a community, evolutionary biologists probably do not appreciate just how relevant our work is to policy makers, industry and society in general. This insularity means that natural solutions to many of humanities’ problems remain hidden from all but a few, and our failure to explain evolution itself means that many solutions currently employed are doomed to fail. A text-book example is the inevitable evolution of pesticide resistance in the face of the strong directional selection imposed by insecticides1.

The strength of the evolutionary algorithm is its simplicity: test a range of variants, select the best, replicate the winning design(s) with some error, and rerun the process. Nature has been running this Research & Development (R&D) routine for about 3 billion years, so the development costs of natural solutions have long been paid. Furthermore, these solutions can be sustainable as they evolve to track moving targets. However, while humanity has employed evolutionary principles for at least 10,000 years in the domestication of plants and animals, we are only just beginning to realize the full range of natural solutions, and their implementation is in its infancy. In addition to providing ready-made solutions, the general principles underlying evolution are remarkably powerful. This natural algorithm is a highly effective problem solving technique that is able to respond rapidly and flexibly to pretty much any challenge. However, this simple and highly functional “design” protocol is remarkably under-used.

So how do we make more of nature’s designs and the method that produced them? Part of the answer is policy related. Until policy makers, within government and other bodies, recognize that evolution is both problem and solution, we will not reap the rewards that are there to be taken. It is incumbent upon us, scientists, to educate institutions to enable this recognition. The evolution of antibiotic resistance is a case in point. This is an increasingly dangerous problem that already results in millions of needless deaths2. If there had been broader understanding that organisms evolve, and rates of evolution depend on the strength of selection, both basic tenants of evolutionary biology, we may not be in this troubling situation. Additionally, guidance to finish antibiotic prescriptions may have been misplaced3,4. High-dose antibiotics select for the evolution of resistance, but also remove non-resistant forms, which can be competitively superior because they do not pay the costs of resistance. Prolonged doses of antibiotics can therefore make it easier for resistant forms to proliferate and occupy now vacant niches, and this in a very real sense, replicates our domestication of plants and animals, showing we have not understood the general principles of evolution at all well.

More recent approaches to antibiotic resistance do incorporate understanding of selection, evolutionary trade-offs and single gene effects on multiple traits (pleiotropy)5. This means that next-generation antibiotic treatments should pose evolutionarily problems that are naturally insoluble by asking bacteria to simultaneously seek multiple incompatible solutions: metaphorically asking them to be both small and large at the same time. Darwinian medicine is an embracement of these principles. This approach does not treat all “disease” symptoms as pathologies, but rather recognizes that some of these are evolved responses of the host to clear infection. Insight like this promises to revolutionise how we deal with health issues like obesity and ageing. The recent utilization of the bacterial immune system to develop CRISPR/Cas9 gene editing and all that this promises6, reveals how harnessing nature’s products can be enormously powerful once we have identified them, and cancer research is similarly being revolutionized by adopting an evolutionary focus7.

However, the importance of evolutionary solutions and thinking extends well beyond health. Consider other major problems facing society at large: energy, food, and clean water. All are impacted by evolution, or are issues that can be confronted using evolutionary principles. For example, using butterfly wings to help design solar cells increases their power output by more than 40%8, bacteria have been identified and used to breakdown pollutants or harvest rare metals from mine waste9, and we can exploit the photosynthetic process to more effectively harvest solar energy10.More prosaically, beetle cuticle can be used to design whiter paper11, and enzymes are now exploited to make bio-reactive detergents12 (Fig 1). A little more speculatively, studying the evolution of cooperation can illuminate the factors that decrease societal discord, inform economic thinking, and increase the effectiveness of drugs13,14.

The failure to fully exploit nature’s solutions, and the method that produces them, lies in part with evolutionary biologist, and we would attest, also to the fact that society does not always see the relevance of evolutionary biology or simply refutes the notion of evolution altogether. However, to make full use of the R&D undertaken by nature, we need 1) funding that supports scientific discovery, because if discovery is not fully underwritten we will never know how many problems have already been solved by nature, and 2) a more effective way to link discoveries to solutions. In the UK, as elsewhere, there has been concerted policy to push the second part of this programme, but this has come at a major cost to the discovery element, even though without discovery, all else fails. For example, discovery funding at one UK research council (NERC) has declined by more than one third in absolute terms in the last 5 years. As a community we need to be far stronger in explaining all this: solutions are almost certainly there, we just need support to find them. We need to ensure that we become part of the decision making process precisely because evolutionary biologists have an understanding of the problems and solutions encompassed by organic evolution, and these ultimately impact on all of us and all that we do15. Ecologists have been far more effective lobbyists than evolutionary biologist, in part because ecology “feels more applied”, in part because it suffers less prejudice, but also because the ecological research community has been more organised. This has resulted in major public concern around loss of biodiversity. Learned ecological societies have been extremely important in this process, and their evolutionary equivalents could learn from them.

The importance of evolutionary thinking is reflected in the increasing number of institutes around the world that are based on evolutionary principles and the inherent sustainability of the solutions they provide (e.g. The Centre for Evolution & Cancer (UK), The Evolution Institute (USA), and The Milner Centre for Evolution (UK)). This growth is a recognition that nature’s R&D provides a veritable gold-mine waiting to be explored by industry, with the promise of major economic benefits with each new discovery. And while evolution is the key to all biology, the principle can be applied even more broadly, as the algorithm can be used to optimize or maximize any process. As a community, we need to lobby funders, policy makers and industry, to educate them and make them aware of the potential benefits and costs posed by organic evolution, and we must also become more engaged in decision making processes. If evolutionary biology is to rightfully claim the distinction it deserves, we all need to be much more engaged in singing its praises, this includes supporting the science and high profile evolutionary activity much more than we do at present.

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Figure 1. Examples of nature’s solutions being employed to solve everyday problems. On the left, principles learned from butterfly basking-behaviour is being used to improve the efficiency of solar-cells8, and on the right, the structural properties of the white beetle cuticle has been used to increase the whiteness of paper11.