matches biological evolution, but how well an evolutionary interpretation of urbanism can help explain observed urban phenomena [3].

Crucially, then, it is in the context of application that the value of transference of concepts is ultimately realised. This is seen in the case of Patrick Geddes, a biologist who applied evolutionary thinking to town planning [4]. In fact, Geddes developed his own, neo-vitalistic version of evolution, which departed from darwinism [3,5] and which was hardly acceptable to mainstream biology [6,7]. Nevertheless, this does not prevent Geddes's town planning ideas from being accepted as useful, as far as they work in town planning terms.

Whereas Derry points to the need to apply Darwin's ideas with scientific rigour [1], we can also learn from Darwin's openness to ideas outside biology. Darwin's evolutionary thinking was informed by knowledge of geology and animal husbandry. Both Darwin and Wallace gained their crucial insights into natural selection after reading Malthus's *Essay on the Principle of Population* [8,9]. Conversely, both Geddes and Karl Marx were wary of Darwin's theory, as they perceived it as originating *outside* biology, in Malthusian economics [4,10]. 'Natural selection' is itself a metaphorical coinage—previously unfamiliar to biologists—and none the worse for it.

Transference of concepts is indeed a matter of give and take. As Geddes applied evolution to town planning [4], his colleague at Dundee University, D'Arcy Thompson, applied engineering principles to animal skeletons [11]. The term 'cell' derives from the Latin word for room; 'ecology' derives from the Greek word for house. Biologists freely refer to 'animal architecture' or 'ecosystem engineering' [12]—without needing approval from architects or engineers. The term 'evolution' was itself imported into biology before being exported again. The meaning of the term has 'evolved,' and will continue to do so. Although some biologists might reasonably be wary of the 'appropriation,' 'generalization' or 'vulgarization' of evolution [1], this should neither discourage free exchange of ideas between disciplines nor deny the value of evolutionary interpretations *outside* biology.

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Letters

Institutional vertebratism threatens UK food security

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As an entomologist, it is tempting to see a deliberate bias against animals without backbones [1], but in reality it is more likely that they are 'not noticed' or fall beneath the radar of research council committees or heads of departments. The evidence for bias, intentional or otherwise, is, however, overwhelming. Insects and allied invertebrates comprise ~78% of the world's macro-biodiversity, whereas vertebrates, even using the most generous estimates, make up less than 3% [2]. Approximately 70% of the papers published by conservation and ecology journals deal with vertebrates [1,2]. Funding for research is similarly biased, and not just in the United Kingdom [3].

Those entomologists and other invertebrate biologists who survive are increasingly ghettoised into specialist niche journals with relatively low impact factors but not correspondingly low acceptance rates. A top entomology journal will typically have an impact factor of less than 3 but still reject 80% of submitted papers. The funding and impact factor effects have had a noticeable impact on the appointment and retention of invertebrate biologists. When appointments are predicated by the number of papers in *Nature*, *PNAS*, *Science* and other multidisciplinary journals, it is obvious that entomologists working in applied (agriculture and forestry) and niche (taxonomy) areas will be overlooked or dismissed out of hand. By contrast, whole-organism zoologists working on charismatic mega-fauna, or structural biologists locating vertebrate drug receptor sites, are able to publish in high-impact, high-visibility journals and thus gain additional funding. This of course has a knock-on effect, in that as the number of invertebrate zoologists in universities declines, the amount of time dedicated to the teaching of those areas declines correspondingly. It is no wonder that there is a dearth of invertebrate knowledge or appreciation in the current generation of researchers.

Unfortunately, climate change means that the number of invasive insects, pests or not, is on the increase [4], while

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the number of people able to recognize and deal with these problems is on the decrease. In the United Kingdom, the situation for future generations of entomologist and pest managers is dire; there is only one entomology degree in the country and that is at Masters level. Traditional plant pathology is virtually extinct [5], and pest management in depth is taught only at Masters level at fewer than a handful of universities [1]. Other European countries have similar problems: medical and veterinary entomologists in France number 100, with half of those over the age of 50 [6]. As fewer and fewer graduates with experience of insects and fungi are produced, the number of teachers at all levels from primary to tertiary with this essential skill suite will also decline, with a corresponding loss in knowledge for the succeeding generation.

Unless something is done soon to remedy the situation, it will be too late and the only animals that the general public will be able to recognize will be polar bears and tigers [5]. By contrast, the number of students being trained at Masters and PhD levels in mammal and bird ecology is out of all proportion to the needs of the world both ecologically and economically. Unless this institutional vertebratism is dealt with proactively and, if necessary, by positive discrimination [1], the world can look forward to torrid times indeed. If the UK government is indeed serious about food security, it is high time that the BBSRC in particular, which has agriculture within its remit, concentrates on supporting agronomy, in particular crop protection, and, most importantly, moves from the bench and the cell out into the field.

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Letters

Evolution *is* intelligent design

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David Sloan Wilson and E.O. Wilson [1] have argued persuasively that natural selection is multilevel and can work on whole groups of organisms or even 'systems.' Even most multicellular 'organisms' are, in fact, collections of organisms in a coordinated system. For example, it has been estimated that as much as 90% of the cells in the human body are genetically 'non-human' (mostly bacteria[*]). Evolution is not just random mutations, it is both the generation of alternatives and natural selection to select the best-suited (i.e. most reproductively successful) designs for ever-changing environments.

That the evolutionary process can 'design' organisms and systems has also been demonstrated with computer simulations. Modern designers of computer code sometimes use 'evolutionary algorithms' that mimic the fundamental evolutionary processes to help 'design' new programs that meet specific goals. These algorithms can often find close to optimal solutions that a conscious design process would miss.

It is also clear that cultural change is an evolutionary process [2]. A culture can be viewed as an interdependent set of world views, institutions and technologies that form a socioecological 'regime' embedded in an ecological context [3]. The evolution of cultures follows rules analogous to those governing the evolution of organisms, but with different units of selection (cultural variants versus genetic variants) and a different method of transmission to the next generation (learning versus genes). It is also clear that humans and their cultures coevolve, with selection occurring at multiple levels.

Thus, evolution is a process that works on multilevel systems to, in a sense, design those systems in a way that functions well and survives. One definition of intelligence is the ability to learn. Therefore, evolution is in a very real sense intelligent: it can learn from experience and improve. It does not do this consciously or, at least, what consciousness there is, is distributed throughout the system, but nevertheless it does produce designs that are the product of an intelligent and adaptive learning process.

Therefore, evolution is an intelligent (as opposed to a 'dumb') design process. Not only does it incorporate random mechanisms (such as genetic mutation) and not-so-random mechanisms (such as sexual reproduction and the conscious creation of new cultural variants) to generate alternatives but it also incorporates selection processes that narrow down those alternatives in a manner analogous to the way that a conscious designer would do. Darwin's original examples of how selection operates used plant and animal breeding programs that

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