Applying Cultural Evolution to Address Climate and Environmental Challenges

Roope O. Kaaronen, Helsinki Institute of Sustainability Science, Faculty of Biological and Environmental Sciences, University of Helsinki

Timothy M. Waring, Mitchell Center for Sustainability Solutions and School of Economics, University of Maine

Monique Borgerhoff Mulder, Max Planck Institute for Evolutionary Anthropology

Abstract

Reducing human impacts on Earth's biological systems is an urgent global priority. However, while the necessary technical solutions are now very well understood, the social process of developing, refining, and implementing those solutions through social, cultural, behavioral and policy change, remains beyond current scientific understanding and technical capacity. We develop the case that the young science of cultural evolution can be of use in achieving sustainable and just human futures. We suggest that the process of cumulative adaptive cultural evolution is directly implicated in the emergence of global anthropogenic ecological destruction. Also, the process of cultural evolution is also involved in any effort to foster the emergence and spread of the practices and policies needed to mitigate human impacts. We review the current research linking cultural evolution to modern climate and environmental challenges and propose a research agenda to accelerate social change towards an environmentally stable future.

Introduction

Scientists have drawn attention to the environmental impacts of human activities for decades (Meadows et al., 1972), with increasingly dire warnings (Cardoso et al., 2020; Ripple et al., 2021). There remains little scientific uncertainty of the anthropogenic causes of biodiversity loss, climate change, and their potentially catastrophic threats for human society (Pörtner et al., 2022). However, societies have been slow to change, even as these impacts become more observable and costly. Consequently, the scientific community has begun to consider the prospect of changing aspects of society, institutions, and behaviours themselves (Bak-Coleman et al., 2021; Hébert-Dufresne et al., 2022; Kinzig et al., 2013).

The mounting evidence of human environmental impacts has generated political pressure and scientific interest in solutions. For example, new applied and normative sciences such as conservation science have emerged. Social scientists increasingly examine how behaviours, norms, and policy might be adjusted to avert catastrophic environmental damage and engage in intergovernmental climate policy. Sustainability science has emerged and diversified with the goal of addressing these environmental challenges with the study of concrete solutions, often focusing on case-driven issues with limited generalizable theory (Levin and Clark 2010). Moreover, the study of sustainability is hampered by disciplinary divides between the natural and social sciences as well as between the social sciences themselves (Schoolman et al., 2012). These problems hinder the potential of providing true solutions (Kates, 2012; Van der Leeuw et al., 2012), and we believe they are linked.

The emerging science of cultural change – the study of cultural evolution – holds unique promise for understanding and addressing the crises of human-natural system sustainability (Brooks et al., 2018) and climate change (Pisor and Jones, 2020). Like the sustainability sciences, the study of human cultural evolution is a young field of research. While its foundational works were written in the 1980s (Boyd and Richerson, 1988; Cavalli-Sforza and Feldman, 1981), its application to environmental sustainability has only just begun (Brooks et al. 2018; Waring et al. 2015a). This chapter is therefore prospective in nature. We argue that the study of human cultural evolution provides a theory of individual and group-level social, institutional, and behavioural change that makes a science of sustainability more tractable and simplifies the search for effective solutions and applications. We will not review the general theory or findings in the science of cultural evolution here (instead, see Henrich 2015; Mesoudi 2011; Laland 2018), but focus on why cultural evolution is of special value to an applied science of sustainability.

Why an applied cultural evolutionary science of sustainability is needed

We suggest the *science* of cultural evolution can be useful in achieving sustainability because the *process* of cultural evolution is implicated in two major ways. First, the process of cultural evolution has been part of the problem, leading to environmentally destructive behaviours and social systems. Second, the process of cultural evolution can be deployed to help boost the innovation and refinement of sustainable solutions, and improve the spread of more sustainable policies, behaviours, and systems through cultural transmission. In short, cultural evolution has been part of the problem, and will need to be part of the solution.

In addition, a modern evolutionary approach is useful in addressing popular beliefs that human nature is fixed, short-sighted, greedy, and individualistic. Atkinson and Jacquet (2021) argue that this simplistic and fixed model of human nature is not only incorrect, but it is also dangerous, limiting our vision of policy alternatives, and reducing the hope for change. The science of cultural evolution shows that human culture is deeply flexible and adaptive. Thus, further research may help build a richer and elaborate popular understanding of human culture and adaptability.

Cultural evolution has been part of the problem. The global environmental problems that face humanity are themselves the partial result of a long-term process of cumulative cultural evolution. The large, complex, industrial societies we have today evolved from the smaller-scale subsistence societies of the past. The adaptive process of cultural evolution itself is thought to have arisen because it gives human groups unprecedented power over their environment and other species (Boyd and Richerson, 1996), and cultural evolution may be outpacing genetic evolution (Perreault 2012; Waring and Wood 2021). Group-structured cultural evolution, group competition and warfare appear to have driven the emergence of large-scale human cooperation (Choi and Bowles, 2007; Handley and Mathew, 2020; Richerson et al., 2016) and enabled the emergence of complex and hierarchical societies (Richerson and Boyd, 1999; Turchin et al., 2013; Turchin and Gavrilets, 2009). This rapid, group-structured cultural and technological evolution has led to the emergence and refinement of technologies and industrial systems of natural resource extraction which lie at the heart of most sustainability problems. In light of this evolutionary history, it has been argued that our species evolved (both genetically and culturally) to exploit resources and grow rather than to conserve resources and remain stable (Snyder, 2020). The science of cultural evolution can help us test hypotheses like this on the emergence of the human dominated biosphere and the environmental challenges we now face.

Cultural evolution can be part of the solution. The science of cultural evolution can help identify the factors that determine whether more sustainable behaviours, beliefs, institutions, and technology (i.e., 'solutions') will spread. The processes of cultural transmission, selection, and adaptation can be levered by clever policy to improve the chances that such solutions do emerge and can spread. This requires understanding both the evolutionary mechanisms and the levels of explanation at play. As an example, carbon dioxide emissions result from the exploitation of fossil fuel energy (*proximate* cause). But humans discovered and refined methods for the extraction and use of fossil fuels through centuries of cumulative cultural evolution (*ultimate* cause). Both causes can be true, but they operate at different causal depth, and lead to different, and complementary intervention points. So, in addition to asking how to reduce environmental impacts within society, we might also ask how to influence societal evolution so that structures that reduce environmental impact are successful enough to spread between societies. We contend that focusing on the population level cultural processes which have caused or could resolve our environmental problems adds useful dimensions to sustainability science. For example, with climate change, in addition to asking how to spur the development of low-carbon energy technologies, we could also be asking how to ensure that low-carbon energy technologies spread unaided as a result of their observable collective societal benefits.

In the remainder of this chapter, we examine how the science of cultural evolution can contribute to the development of environmental sustainability as an adaptive societal feature. We explore this topic at the individual level and at higher levels of social organization. Our review covers the transmission of cultural traits (including social learning and transmission biases among individuals and groups), cumulative evolution (including the feedback loops that lead to path-dependencies and cultural niche construction), multilevel selection, and the significance of trait covariance structures.

Cultural evolution of traits among individuals

Evolutionary theory is most distinctive, and perhaps most useful, for its focus on traits and their transmission among individuals. Studying at the individual level is useful because this is the most tangible level at which the context-dependent costs and benefits of behavioural change are realised (Alvard, 1998; Penn, 2003). Individual-level selection pressures strongly influence whether and how new traits, including environmental behaviours, emerge or do not emerge. Analysing where, when and why individuals act to conserve resources brings evolutionary analyses closely in line with traditions in economic, psychological, and anthropological research (Borgerhoff Mulder and Coppolillo, 2005; Hames et al., 1987; Smith and Wishnie, 2000).

Unlike the concept 'sustainability', which is more typically applied to an environmental resource or group-level outcome, definitions of conservation have focused on individual acts. To study the evolution of conservation, we must identify a cultural trait which satisfies some definition of conservation when expressed. While there has been considerable debate over whether conservation traits are necessarily costly (e.g., Ruttan, 1998), whether they require the intent of the actor (Smith 1995), and whether they are evidenced by favourable ecological outcomes (Alvard 1994), evolutionary scientists propose defining a conservation trait as one which promotes acts that not only reduce (or prevent) adverse environmental outcomes but are 'designed' so to do, by the operation of *some mechanism* (Ruttan and Borgerhoff Mulder, 1999; Smith, 1995). Understanding the individual and evolutionary mechanisms of 'design', such as the selection of cultural traits (Boyd and Richerson, 2005), is of fundamental importance if we want to promote the spread of cooperative and/or conservation traits to address sustainability and climate challenges.

Furthermore, conservation acts are typically cooperative in nature. The study of pro-environmental behaviour commonly finds that it is linked with cooperative and prosocial inclinations (Kollmuss and Agyeman, 2002). One important form of prosocial behavior is 'altruistic punishment,' in which cooperators punish non-cooperators at a personal cost. For example, in a Mexican city, the tolerance of antisocial behaviour generally is correlated with wasteful use of scarce water resources (Corral-Verdugo et al., 2003; Corral-Verdugo and Frías-Armenta, 2006). Prosocial traits may be personality traits or the result of conditioning. For example, pro-environmental attitudes are correlated with pro-social attitudes among university students, and are explained by the experience of a nurturing home environment (Bhattacharya, 2019; Waring et al., 2016).

With these definitions or environmentally relevant cultural traits in mind we can explore the processes of social learning and cultural transmission, the way in which traits are distributed and clustered within populations, and the reciprocal causation entailed in cultural niche construction.

Learning – social and individual

Learning, both social and asocial (individual), is a central consideration in cultural evolution research. The human capacity for cumulative cultural evolution through the social learning of traits is one of the features that sets us most apart from other animal species (Henrich 2015; Laland 2018). However, those learning mechanisms are often biased by various adaptive cues, or 'social learning biases.' So, when individuals copy new behaviours from others, they often focus on imitating people they regard as knowledgeable, prestigious, or successful (Jiménez and Mesoudi, 2019), or simply adopting the traits of the majority to benefit from coordination or accumulated experience (Henrich and Boyd 1998). Furthermore, in deciding whom and what to copy people also evaluate the likely consequences of trait adoption, through pay-off biased learning (Kendal, Giraldeau, and Laland 2009).

Experimental studies reveal a lot about how and why individuals vary their social learning strategies (Kendal et al. 2018). It is also clear that individuals do not always make the "right" choices with respect to an economic or fitness calculus (Rendell et al., 2010), thereby directing cultural evolutionists' attention to the biases that might affect which traits are preferred. Herein lies a potential toolbox from which cultural evolutionists can contribute to sustainability science, by identifying the biases, heuristics and transmission mechanisms that direct social learning. As an example, hotel towel reuse is promoted more efficiently by noting that this is what the majority of guests do, rather than providing other motivational prompts or education about the costs associated with laundering (Goldstein et al., 2008). Meta-analysis reveals that interventions which describe common behaviour ('descriptive norms') are powerful tools in enhancing the uptake of pro-environmental behaviour (Farrow et al., 2017). Scaling these insights into more environmentally impactful domains could be promising.

Individual traits vary in complexity, and the complexity of behaviours has drastic implications on how they spread in social networks. For instance, it has been suggested that complex social behaviours – those that require social affirmation from multiple sources – spread differently to simple behaviours, which spread through individual contact, much like viruses (Centola, 2018; Centola and Macy, 2007). So, whereas some environmentally relevant cultural traits (e.g., the adoption of a cheap green technology) may act like 'simple contagions,' spreading through one influential node in a social network (e.g., a social influencer), many important traits operate more like 'complex contagions,' requiring multiple, repeated contact, and strong social ties to spread. For example, a person does not adopt an environmentally friendly vegan diet as a result of a single exposure to the idea. Instead, individuals arrive at that decision through a long personal and social process of reflection and discussion. This is likely be true for many environmentally relevant traits such as participation in social movements or political campaigns for environmental causes or candidates. Indeed, this may be why Berl et al. (2022) found such low transmission of complex "science-based information" in their experimental manipulations of wolf conservation materials.

It is also important to recognise that individuals can, and often do, puzzle things out on the basis of their own experiences (individual or asocial learning), even though this can be costly in terms of time, energy and foregone opportunities. In fact, while selection favours social learning in relatively slowly changing environments (Perreault et al., 2012), the unprecedented pace of environmental change in the Anthropocene will probably put a premium on individual creativity and innovation. Rapidly changing environments result in *cultural evolutionary mismatch* (Lloyd et al., 2011): old or traditional knowledge might have low fitness in radically altered environments (Kaaronen et al., 2021), making individual creativity indispensable. Cultural evolutionary modelling shows how the emergence of new traits, and complexity more generally, is associated with environmental unpredictability, population size and connectivity (Fogarty et al., 2015). Understanding such processes better will help source new ideas for reducing and/or reversing environmental harm.

Trait diversity and covariance structures

Cultural evolutionists also consider the diversity of traits in the population (Kaaronen et al., 2021), and their covariance structure (Jones et al., 2021). A population can be described by its pool of cultural traits, and their patterning, shaped either by natural or and social. We know, for example, that diverse subsistence strategies buffer populations against food shortages (Halstead and O'Shea, 2004), diverse material technologies and tools can facilitate human adaptation to changing environments (Manninen and Knutsson, 2014), and diversity in opinions and team structures can help organisations succeed in competitive ever-evolving industrial economies (Page, 2019).

Cultural traits are also rarely entirely independent of one another (i.e., they covary). This means that by promoting one trait, one also promotes other, correlated traits that might "culturally hitchhike" (Yeh, Fogarty, and Kandler 2019). Covariance structures can interact with sustainability interventions to have both negative and positive effects. As an example of a negative outcome, imagine how a project encouraging farmers to copy a targeted trait of more successful farmers (such as improved seeds) could lead to the imitation of other related behaviours, such as pesticide use. Another example of the challenge of trait covariances comes from the adoption of green technology (Smaldino et al., 2017): if a low impact technology becomes statistically associated with a certain social identity, that association can easily limit the diffusion to other social identities, especially in a polarized society. Research on behavioural interventions around harmful sexual traditions such as female genital cutting have shown the same effects, in which correlation between the target behaviour and a social identity can limit its spread, so a practitioners should utilize a representative sample in the intervention (Efferson et al., 2020).

In fact, it is precisely such covariances that are encouraging development economists to design more complex ("bundled") interventions that allow for beneficial interactions (such as combining improved seeds with insurance, see Boucher et al. 2022). Covariance structures might also have positive effects. As a group-level example, Oliver et al. (2015) report how the success of an effective periodic octopus closure in Madagascar led to communities adopting a broad suite of conservation management actions, such as banning destructive fishery gear and founding permanent no-take marine reserves. In short, the clustering and correlation of traits can result in interventions having unexpected side-effects with both negative and positive impacts on sustainability. Again, this provides another way to improve policy and intervention design.

Cultural niche construction

An evolutionary framework pushes us to evaluate the impact of cultural traits against the environment in which they are observed. However, many traits modify the environment itself. A useful framework in this regard is that of niche construction, the process whereby organisms alter their environments, and in so doing change the selective pressure to which they are subject (Laland, Odling-Smee, and Feldman 2001). Cultural niche construction simply derives from cultural, rather that genetic, adaptations. Agriculture, for example, is a powerful cultural niche-constructing activity. It not only transforms abiotic, biotic and social environments, but in modifying the environment it affects the selective value of different social and biological traits, in our species and others, including our norms and values (Altman and Mesoudi, 2019). A modern example is the self-reinforcing feedbacks between built infrastructure such as fossil fuel energy infrastructure and individual behaviour, such as driving, heating, and cooking with fossil fuels. The two-way dynamics of niche construction models can be leveraged to produce behavioural change. For example, Kaaronen and Strelkovskij (2020) show how unsustainable habits promoted by our social and material environments can be dislodged through intentional infrastructural change. More specifically they show how the well-designed bicycle infrastructures of Amsterdam and Copenhagen promoted the rapid evolution of a bicycling culture. The most important environmental traits are therefore often niche-constructing traits, many of which are traits that characterize groups rather than individuals, bringing us to the analysis of sustainability at higher levels of social organization.

Cultural evolution among groups

A useful aspect of cultural evolutionary theory is that the core Darwinian principles (variation, selection, transmission) can apply at any scale of social or biological organization, from individuals to multi-national bodies (Wilson, 2020). Accordingly, cultural evolution can be applied to the study of the evolution of institutions (as a group-level cultural trait) and organizations (as the groups that adopt those traits) (Currie et al., 2016). Thus, we can consider environmental laws, policies, and social systems as group-level cultural traits which emerge, evolve, and spread between groups of all types, private, political, religious, formal and informal. While some group-level cultural traits can be decomposed into a distribution of individual traits such as shared norms, here we mostly refer to group-level cultural traits such as institutions, group size, and infrastructure which are inherently group-level properties (Smaldino, 2014). Group-level cultural traits are of central importance in sustainability endeavours (Waring et al., 2015a).

Any group-level trait may be of interest, from a green-washing institutional practice or a social incentive for efficient transportation to a global carbon tax. But, perhaps the most important set of group-level traits are those than enable groups to cooperate, share and collectively manage a limited environmental resource despite conflicts of interest over its use. Ostrom (1990) identified a set of ‘institutional design principles’ which were commonly found to enhance the efficacy of groups in natural resource management. Together, these principles generally help to align individual and collective interests, helping to maintain cooperation. Systematic analyses of how the design principles, or proxies thereof, enable sustainable outcomes show that different traits will be important for different resource systems (Cox et al., 2010), and that some traits only work in conjunction with others (Baggio et al., 2014). A major strength of Ostrom’s empirical findings was their generality. Her design principles appear to help groups self-organise, solve free rider problems, and achieve shared goals in any context. Therefore, the design principles might well be useful for the efficacy and survival of groups in a broad evolutionary sense, and even apply to groups at any scale (Wilson, 2020; Wilson et al., 2020). An important area of research is therefore identifying the conditions for the evolution of adaptive group-level traits that support reduced environmental impact, and an important area of application is in facilitating their spread between groups.

Transmission of traits between groups

Institutions and group-level traits can diffuse or spread between groups, but the specific process of the cultural transmission of institutions is not yet very well understood. Akin to the idea of complex contagion at the individual level, some group-level institutional traits may be slow to transmit while others might constitute organizational fads. Moreover, the transmission of policy can be influenced by population (e.g. city size) and economic competition between political units (Shipan and Volden, 2008). Empirical research has outlined a set of factors that influence the diffusion of environmental policy (Tews, 2005). First, policies that aim to slow long-term environmental harm typically diffuse at slower rates than shorter term policies aimed at improving profitability. Second, incremental policies that are compatible with existing policies are found to diffuse more rapidly than major or transformative policies. And third, policy innovations that conflict with the interests of the socioeconomically powerful groups are less likely to spread. In addition to these internal political barriers, direct between-state policy transmission and other mechanisms of transmission may be at work as well (Tews, 2005). Tews also found that national environmental policies are evolving to become increasingly similar through the action of international cooperation (via organizations such as Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (I.P.B.E.S.) and the Intergovernmental Panel on Climate Change (I.P.C.C.). Currently, environmental policy diffusion has not been studied from an evolutionary perspective, although the barriers and opportunities to the spread of institutional interventions both within and between subpopulations have been well depicted by some development economists (Bulte et al., 2018). More generally, although the scale is different, contextual factors, costs and complexity influence the transmission of group-level environmental traits as they do individual-level traits. Thus, one useful approach might be to test how similar the group-level transmission of policy is to the individual processes of social learning (Kendal et al., 2018).

Selection of group-level traits

Group-level cultural traits can contribute to the adaptive success of human groups that take them on, leading to a group-level process of cultural adaptation. Cultural group selection (Henrich, 2004; Wilson, 2020), or group-structured cultural selection (Zefferman and Mathew, 2015), has probably been important human evolution. Evidence for cultural group selection is pervasive (Richerson et al., 2016). Cultural group selection explains the emergence and spread of cultural traits (both individual and group) as a result of the competitive advantage they provide to an adopting group. Waring and co-authors have developed an analytical framework designed to detect cases in which cultural group selection favours more sustainable environmental outcomes (Waring et al., 2015b). For example, in an analysis of the institutional principles employed by cooperative businesses, Waring and co-authors (Waring et al., 2021) discovered that over their 170 year history, these 'co-operative principles' can be seen to benefit the success of co-operatives, and to spread widely, perhaps as a consequence of their beneficial effects. This research suggests that group-level benefits can impact the transmission of traits, leading to adaptive group-level cultural evolution. Moreover, competition between companies in an industry has been shown to increase the trust of employees within those companies (Francois et al., 2018).

On one hand, cultural group selection has more than likely helped drive carbon emissions and environmental destruction. For example, cultural group selection via market competition for energy resources almost certainly helped to refine and spread the fossil fuel technology and infrastructure between companies and countries in the last two centuries. The immediate economic benefits of energy resources can be very large, creating traits that benefit individuals and groups simultaneously. In such situations, there is no social dilemma or conflict between individuals (employees) and their groups (companies). Studying this history as a process of adaptive cultural group selection might reveal useful information for future industrial policy.

On the other hand, cultural group selection can also be important in the evolution of environmentally beneficial traits. For example, decades of research on the informal social structures of the Maine lobstering industry suggests that many of the common territorial management practices and possibly conservation behaviours emerged due to cultural group selection between tight-knit groups of lobstermen called ‘harbor gangs’ (Waring and Acheson, 2018). Another example comes from the spread of community forestry institutions on Pemba island, Tanzania (Andrews and Borgerhoff Mulder, 2018). This research has exposed evidence that pay-off biased learning can, under certain circumstances, lead to the spread of community forest management institutions (Borgerhoff Mulder et al., 2021). In both cases the presence of defensible territorial resource claims proved important in the evolution of institutions to protect those resources.

This research endeavour is hopeful in challenging times: institutions for more sustainable resource management can evolve culturally. Moreover, the cultural multilevel selection framework helps predict when and where that might occur.

Cultural evolution at multiple levels

In most cases, the traits and behaviours of both groups and individuals will matter in determining environmental outcomes. This is especially the case in most difficult sustainability challenges which pit individual interests against those of the larger group. In these environmental social dilemmas, cooperative individual behaviours are likely to remain scarce without institutional support from the group. Individual behaviours (such as cooperation) and group-level traits (such as rules that punish non-cooperation) both matter simultaneously. In such cases, cultural evolution researchers can draw on the framework of cultural multilevel selection (Waring et al., 2015). The cultural multilevel selection framework simply suggests that selective cultural evolution might happen on any of numerous levels of social organization, and even multiple levels at once. The dynamics can be understood by answering the question on which level the strength of cultural selection is the strongest, and the Price equation (Frank, 1995) can be employed to help distinguish forces acting on both levels of selection. This framework has been usefully applied in several cases (Andrews and Borgerhoff Mulder, 2018; Waring et al., 2021; Waring and Acheson, 2018). Kline et al (2018) provide a guide for studying group-level cultural evolution in the domain of sustainability.

However, not all environmental social dilemmas can be resolved via ‘competition’ on the level above. Global climate change and biodiversity challenges are likely the most pressing sustainability challenges facing humanity, largely because there is no higher level (planetary) of organization to select for global collective action between countries. Indeed, despite various attempts at global cooperation, such as the Paris Agreement and the Aichi Biodiversity Targets, results have been lacklustre. The Paris Agreement seems unlikely to meet its goals, and the international community did not fully achieve a single one of the 20 Aichi biodiversity targets agreed in Japan in 2010. The idea of ‘climate clubs’, where smaller groups of states form cooperative climate and economic agreements, effectively competing with non-club nations has been proposed as a route to establishing international cooperation (Potoski, 2017). But, as Zefferman (2018) points out, the reduced greenhouse gas emissions produced by cooperating countries are ultimately non-excludable, such that cooperation can unravel due to free riding among nations. For club selection to work the benefits must be largely contained within the club, or non-members must suffer costs that exceed the costs of joining the club. Recent modelling suggests that more complex structures, composed of voluntary agreements within multiple overlapping cooperative forums, may serve to increase the influence of cooperators, and facilitate a greater generation of non-excludable public goods (Vasconcelos et al 2020).

Ultimately, however, the climate challenge is unlikely to be solved simply through cultural multilevel selection. Technological innovation through strong competition may help produce solutions in some persistent problems if those who produce sustainable technologies more efficiently out-compete those who do not. Zefferman (2018) argues, fostering competition over innovative technologies may reduce the threshold for collective action over a public good, such as reduced greenhouse gas. However, even technological solutions are complicated by the fact that technological and economic growth are currently not sufficiently decoupled from environmental harms (Vadén et al., 2020). This places an even higher pressure for fundamental change in institutionalised growth-oriented norms and values.

Conclusion

We suspect that an interdisciplinary science of social, cultural, and institutional evolution can be useful for humanity and the preservation of Earth's capacity to support biodiversity and a healthy human population. But there is a lot of work to do. Climate and ecosystem change have advanced to the point where, even if full mitigation efforts took place, humans will face considerable challenges in adapting to altered climates and ecosystems. The environments in the Anthropocene will drastically differ from those in the Holocene past (Steffen et al., 2015). This will result in multiple ecological, economic, and climatic uncertainties, and major adaptive challenges to come. Cultural evolutionary theory can help us understand and prepare for these perturbations (Kaaronen et al., 2021). In this unprecedented ecological moment we need new research that not only brings sustainable solutions to scale, but changes the structure of society by linking the evolution of institutions and beneficial behaviour in a self-reinforcing manner (Hébert-Dufresne et al., 2022). There are many hopeful signs, however, as described in the examples above, and an applied science of cultural evolution for sustainability is possible. To advance that research agenda, we conclude with a set of new research questions.

(1) *How did environmentally destructive industries, behaviours and technologies evolve in the recent past?*

(2) *How do the short-term forces of human cultural adaptation diverge from long-term sustainable outcomes today?*

(3) *How can non-destructive replacement technologies, behaviours, and institutions emerge and spread going forward?*

(4) *What can we learn from evolutionary theory to increase the adaptive capacities of human societies in the future?*

The field of cultural evolution, uniquely positioned at the intersection of the natural and social sciences, has potential to improve our understanding of how human societies adapt to their environments, and therefore also has the potential to help us do so on the accelerated timeframe necessary for contemporary sustainability crises. Although it has yet to be fully demonstrated, we remain optimistic that the science of cultural evolution can help us conserve what needs to be maintained and evolve what needs to be changed.

References

Altman, A., Mesoudi, A., 2019. Understanding agriculture within the frameworks of cumulative cultural evolution, gene-culture co-evolution, and cultural niche construction. Hum. Ecol. 47, 483–497.

Alvard, M.S., 1998. Evolutionary ecology and resource conservation. Evol. Anthropol. Issues News Rev. Issues News Rev. 7, 62–74.

Andrews, J., Borgerhoff Mulder, M., 2018. Cultural group selection and the design of REDD+: insights from Pemba. Sustain. Sci. 13, 93–107.

Atkinson, Q.D., Jacquet, J., 2021. Challenging the Idea That Humans Are Not Designed to Solve Climate Change. Perspect. Psychol. Sci. 17456916211018454. https://doi.org/10.1177/17456916211018454

Baggio, J.A., Barnett, A., Perez-Ibarra, I., Brady, U., Ratajczyk, E., Rollins, N., Rubinos, C., Shin, H.S., Yu, D.J., Rimjhim, A., 2014. The puzzle of good governance: Putting the pieces together through the lens of ostroms design principles. CSID Work Pap Ser.

Bak-Coleman, J.B., Alfano, M., Barfuss, W., Bergstrom, C.T., Centeno, M.A., Couzin, I.D., Donges, J.F., Galesic, M., Gersick, A.S., Jacquet, J., 2021. Stewardship of global collective behavior. Proc. Natl. Acad. Sci. 118, e2025764118.

Berl, R.E., Sekar, S., Markevich, A., Camara, C., Niemiec, R.M., 2022. Assessing the impacts of normative and efficacy-based messaging on the social diffusion of conservation science. Conserv. Sci. Pract. 4, e12647.

Bhattacharya, H., 2019. Do pro-social students care more for the environment? Int. J. Sustain. High. Educ. 20, 761–783. https://doi.org/10.1108/IJSHE-11-2018-0223

Borgerhoff Mulder, M., Caro, T., Ngwali, A.S., 2021. A silver lining to REDD: Institutional growth despite programmatic failure. Conserv. Sci. Pract. 3, e312. https://doi.org/10.1111/csp2.312

Borgerhoff Mulder, M., Coppolillo, P., 2005. Conservation: Linking Ecology, Economics, and Culture. Princeton University Press.

Boucher, S.R., Carter, M.R., Flatnes, J.E., Lybbert, T.J., Malacarne, J.G., Marenya, P., Paul, L.A., 2022. Bundling Genetic and Financial Technologies for More Resilient and Productive Small-scale Agriculture (Working Paper No. 29234), Working Paper Series. National Bureau of Economic Research. https://doi.org/10.3386/w29234

Boyd, R., Richerson, P.J., 2005. The origin and evolution of cultures. Oxford University Press.

Boyd, R., Richerson, P.J., 1996. Why culture is common, but cultural evolution is rare, in: Proceedings-British Academy. Oxford University Press Inc., pp. 77–94.

Boyd, R., Richerson, P.J., 1988. Culture and the evolutionary process. University of Chicago press.

Brooks, J.S., Waring, T.M., Borgerhoff Mulder, M., Richerson, P.J., 2018. Applying cultural evolution to sustainability challenges: an introduction to the special issue. Sustain. Sci. 13, 1–8.

Bulte, E., Richards, P., Voors, M., 2018. Institutions and agrarian development: a new approach to West Africa. Springer.

Cardoso, P., Barton, P.S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Fukushima, C.S., Gaigher, R., Habel, J.C., Hallmann, C.A., Hill, M.J., Hochkirch, A., Kwak, M.L., Mammola, S., Ari Noriega, J., Orfinger, A.B., Pedraza, F., Pryke, J.S., Roque, F.O., Settele, J., Simaika, J.P., Stork, N.E., Suhling, F., Vorster, C., Samways, M.J., 2020. Scientists' warning to humanity on insect extinctions. Biol. Conserv. 242, 108426. https://doi.org/10.1016/j.biocon.2020.108426

Cavalli-Sforza, L.L., Feldman, M.W., 1981. Cultural transmission and evolution: A quantitative approach. Princeton University Press.

Centola, D., 2018. How Behavior Spreads: The Science of Complex Contagions. Princeton University Press.

Centola, D., Macy, M., 2007. Complex Contagions and the Weakness of Long Ties. Am. J. Sociol. 113, 702–734. https://doi.org/10.1086/521848

Choi, J.-K., Bowles, S., 2007. The Coevolution of Parochial Altruism and War. Science 318, 636–640.

Corral-Verdugo, V., Frias-Amenta, M., Gonzalez-Lomelí, D., 2003. On the Relationship Between Antisocial and Anti-Environmental Behaviors: An Empirical Study. Popul. Environ. 24, 273–286. https://doi.org/10.1023/A:1021251128081

Corral-Verdugo, V., Frías-Armenta, M., 2006. Personal Normative Beliefs, Antisocial Behavior, and Residential Water Conservation. Environ. Behav. 38, 406–421. https://doi.org/10.1177/0013916505282272

Cox, M., Arnold, G., Tomás, S.V., 2010. A Review of Design Principles for Community-based Natural Resource Management. Ecol. Soc. 15.

Currie, T.E., Turchin, P., Bednar, J., Richerson, P.J., Schwesinger, G., Steinmo, S., Wacziarg, R., Wallis, J.J., 2016. Evolution of Institutions and Organizations, in: Wilson, D.S., Kirman, A. (Eds.), Complexity and Evolution: Toward a New Synthesis for Economics. The MIT Press. https://doi.org/10.7551/mitpress/9780262035385.003.0012

Efferson, C., Vogt, S., Fehr, E., 2020. The promise and the peril of using social influence to reverse harmful traditions. Nat. Hum. Behav. 4, 55–68. https://doi.org/10.1038/s41562-019-0768-2

Farrow, K., Grolleau, G., Ibanez, L., 2017. Social Norms and Pro-environmental Behavior: A Review of the Evidence. Ecol. Econ. 140, 1–13. https://doi.org/10.1016/j.ecolecon.2017.04.017

Fogarty, L., Creanza, N., Feldman, M.W., 2015. Cultural evolutionary perspectives on creativity and human innovation. Trends Ecol. Evol. 30, 736–754.

Francois, P., Fujiwara, T., van Ypersele, T., 2018. The origins of human prosociality: Cultural group selection in the workplace and the laboratory. Sci. Adv. 4.

Frank, S.A., 1995. George Price's contributions to evolutionary genetics. J. Theor. Biol. 175, 373–388. https://doi.org/10.1006/jtbi.1995.0148

Goldstein, N.J., Cialdini, R.B., Griskevicius, V., 2008. A Room with a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels. J. Consum. Res. 35, 472–482. https://doi.org/10.1086/586910

Halstead, P., O'Shea, J., 2004. Bad Year Economics: Cultural Responses to Risk and Uncertainty. Cambridge University Press.

Hames, R., McCay, B.J., Acheson, J.M., 1987. Game conservation or efficient hunting, in: In The Question of the Commons. The Culture and Ecology of Communal Resources. University of Arizona Press, Tucson, AZ, pp. 92–107.

Handley, C., Mathew, S., 2020. Human large-scale cooperation as a product of competition between cultural groups. Nat. Commun. 11, 702. https://doi.org/10.1038/s41467-020-14416-8

Hébert-Dufresne, L., Waring, T.M., St-Onge, G., Niles, M.T., Kati Corlew, L., Dube, M.P., Miller, S.J., Gotelli, N.J., McGill, B.J., 2022. Source-sink behavioural dynamics limit institutional evolution in a group-structured society. R. Soc. Open Sci. 9, 211743. https://doi.org/10.1098/rsos.211743

Henrich, J., 2015. The Secret of our Success: How Culture is Driving Human Evolution, Domesticating our Species, and Making us Smarter. Princeton University Press.

Henrich, J., 2004. Cultural group selection, coevolutionary processes and large-scale cooperation. J. Econ. Behav. Organ. 53, 3–35. https://doi.org/10.1016/S0167-2681(03)00094-5

Henrich, J., Boyd, R., 1998. The evolution of conformist transmission and the emergence of between-group differences. Evol. Hum. Behav. 19, 215–241. https://doi.org/10.1016/S1090-5138(98)00018-X

Jiménez, Á.V., Mesoudi, A., 2019. Prestige-biased social learning: current evidence and outstanding questions. Palgrave Commun. 5, 1–12. https://doi.org/10.1057/s41599-019-0228-7

Jones, J.H., Ready, E., Pisor, A.C., 2021. Want climate-change adaptation? Evolutionary theory can help. Am. J. Hum. Biol. 33, e23539. https://doi.org/10.1002/ajhb.23539

Kaaronen, R.O., Manninen, M.A., Roe, E., Hukkinen, J.I., Eronen, J.T., 2021. Lessons for human survival in a world without ecological templates: what can we learn from small-scale societies? Ecol. Soc. 26.

Kaaronen, R.O., Strelkovskii, N., 2020. Cultural evolution of sustainable behaviors: Pro-environmental tipping points in an agent-based model. One Earth 2, 85–97. https://doi.org/10.1016/j.oneear.2020.01.003

Kates, R.W., 2012. From the unity of nature to sustainability science: ideas and practice, in: Sustainability Science. Springer, pp. 3–19.

Kendal, J., Giraldeau, L.-A., Laland, K., 2009. The evolution of social learning rules: Payoff-biased and frequency-dependent biased transmission. J. Theor. Biol. 260, 210–219. https://doi.org/10.1016/j.jtbi.2009.05.029

Kendal, R.L., Boogert, N.J., Rendell, L., Laland, K.N., Webster, M., Jones, P.L., 2018. Social learning strategies: Bridge-building between fields. Trends Cogn. Sci. 22, 651–665.

Kinzig, A.P., Ehrlich, P.R., Alston, L.J., Arrow, K., Barrett, S., Buchman, T.G., Daily, G.C., Levin, B., Levin, S., Oppenheimer, M., 2013. Social norms and global environmental challenges: the complex interaction of behaviors, values, and policy. BioScience 63, 164–175.

Kline, M.A., Waring, T.M., Salerno, J., 2018. Designing cultural multilevel selection research for sustainability science. Sustain. Sci. 13, 9–19. https://doi.org/10.1007/s11625-017-0509-2

Kollmuss, A., Agyeman, J., 2002. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environ. Educ. Res. 8, 239–260. https://doi.org/10.1080/13504620220145401

Laland, K.N., 2018. Darwin's Unfinished Symphony: How Culture Made the Human Mind. Princeton University Press.

Laland, K.N., Odling-Smee, J., Feldman, M.W., 2001. Cultural niche construction and human evolution. J. Evol. Biol. 14, 22–33. https://doi.org/10.1046/j.1420-9101.2001.00262.x

Levin, S.A., Clark, W., 2010. Toward a science of sustainability. Cent. Int. Dev. Work. Pap.

Lloyd, E., Wilson, D.S., Sober, E., 2011. Evolutionary mismatch and what to do about it: A basic tutorial. Evol. Appl. 2–4.

Manninen, M.A., Knutsson, K., 2014. Lithic raw material diversification as an adaptive strategy—Technology, mobility, and site structure in Late Mesolithic northernmost Europe. J. Anthropol. Archaeol. 33, 84–98. https://doi.org/10.1016/j.jaa.2013.12.001

Meadows, D.H., Meadows, D.H., Randers, J., Behrens III, W.W., 1972. The limits to growth: a report to the club of Rome (1972). Google Sch. 91.

Mesoudi, A., 2011. Cultural Evolution. University of Chicago Press.

Oliver, T.A., Oleson, K.L.L., Ratsimbazafy, H., Raberinary, D., Benbow, S., Harris, A., 2015. Positive Catch & Economic Benefits of Periodic Octopus Fishery Closures: Do Effective, Narrowly Targeted Actions 'Catalyze' Broader Management? PLOS ONE 10, e0129075. https://doi.org/10.1371/journal.pone.0129075

Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.

Page, S., 2019. The diversity bonus, in: The Diversity Bonus. Princeton University Press.

Penn, D.J., 2003. The Evolutionary Roots of Our Environmental Problems: Toward a Darwinian Ecology. Q. Rev. Biol. 78, 275–301. https://doi.org/10.1086/377051

Perreault, C., 2012. The pace of cultural evolution. PLoS One 7, e45150.

Perreault, C., Moya, C., Boyd, R., 2012. A Bayesian approach to the evolution of social learning. Evol. Hum. Behav. 33, 449–459. https://doi.org/10.1016/j.evolhumbehav.2011.12.007

Pisor, A., Jones, J.H., 2020. Human adaptation to climate change: An introduction to the special issue. PsyArXiv. https://doi.org/10.31234/osf.io/sw8nh

Pörtner, H.O., Roberts, D.C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R.A., Betts, R., Kerr, R.B., Biesbroek, R., 2022. Climate change 2022: impacts, adaptation and vulnerability.

Potoski, M., 2017. Green clubs in building block climate change regimes. Clim. Change 144, 53–63. https://doi.org/10.1007/s10584-015-1517-9

Rendell, L., Boyd, R., Cownden, D., Enquist, M., Eriksson, K., Feldman, M.W., Fogarty, L., Ghirlanda, S., Lillicrap, T., Laland, K.N., 2010. Why copy others? Insights from the social learning strategies tournament. Science 328, 208–213.

Richerson, P., Baldini, R., Bell, A.V., Demps, K., Frost, K., Hillis, V., Mathew, S., Newton, E.K., Naar, N., Newson, L., Ross, C., Smaldino, P.E., Waring, T.M., Zefferman, M., 2016. Cultural group selection plays an essential role in explaining human cooperation: A sketch of the evidence. Behav. Brain Sci. 39. https://doi.org/10.1017/S0140525X1400106X

Richerson, P.J., Boyd, R., 1999. Complex societies: The evolutionary origins of a crude superorganism. Hum. Nat. 10, 253–289. https://doi.org/10.1007/s12110-999-1004-y

Ripple, W.J., Wolf, C., Newsome, T.M., Gregg, J.W., Lenton, T.M., Palomo, I., Eikelboom, J.A.J., Law, B.E., Huq, S., Duffy, P.B., Rockström, J., 2021. World Scientists' Warning of a Climate Emergency 2021. BioScience 71, 894–898. https://doi.org/10.1093/biosci/biab079

Ruttan, L.M., 1998. Closing the Commons: Cooperation for Gain or Restraint? Hum. Ecol. 26, 43–66.

Ruttan, L.M., Borgerhoff Mulder, M., 1999. Are East African pastoralists truly conservationists? Curr. Anthropol. 40, 621–652.

Schoolman, E.D., Guest, J.S., Bush, K.F., Bell, A.R., 2012. How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. Sustain. Sci. 7, 67–80.

Shipan, C.R., Volden, C., 2008. The Mechanisms of Policy Diffusion. Am. J. Polit. Sci. 52, 840–857.

Smaldino, P.E., 2014. The cultural evolution of emergent group-level traits. Behav. Brain Sci. 37, 243–254. https://doi.org/10.1017/S0140525X13001544

Smaldino, P.E., Janssen, M.A., Hillis, V., Bednar, J., 2017. Adoption as a social marker: Innovation diffusion with outgroup aversion. J. Math. Sociol. 41, 26–45. https://doi.org/10.1080/0022250X.2016.1250083

Smith, E.A., 1995. Comment on: Intraspecific prey choice by Amazonian hunters. By M. Alvard. Curr. Anthropol. 36, 810–811.

Smith, E.A., Wishnie, M., 2000. Conservation and Subsistence in Small-Scale Societies. Annu. Rev. Anthropol. 29, 493–524.

Snyder, B.F., 2020. The genetic and cultural evolution of unsustainability. Sustain. Sci. 15, 1087–1099.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., 2015. The trajectory of the Anthropocene: The Great Acceleration. Anthr. Rev. 2, 81–98. https://doi.org/10.1177/2053019614564785

Tews, K., 2005. The diffusion of environmental policy innovations: cornerstones of an analytical framework. Eur. Environ. 15, 63–79. https://doi.org/10.1002/eet.378

Turchin, P., Currie, T.E., Turner, E.A.L., Gavrilets, S., 2013. War, space, and the evolution of Old World complex societies. Proc. Natl. Acad. Sci. 201308825. https://doi.org/10.1073/pnas.1308825110

Turchin, P., Gavrilets, S., 2009. Evolution of complex hierarchical societies. Soc. Hist. Evol. 8, 167–198.

Vadén, T., Lähde, V., Majava, A., Järvensivu, P., Toivanen, T., Hakala, E., Eronen, J.T., 2020. Decoupling for ecological sustainability: A categorisation and review of research literature. Environ. Sci. Policy 112, 236–244. https://doi.org/10.1016/j.envsci.2020.06.016

Van der Leeuw, S., Wiek, A., Harlow, J., Buizer, J., 2012. How much time do we have? Urgency and rhetoric in sustainability science. Sustain. Sci. 7, 115–120.

Waring, T., Acheson, J., 2018. Evidence of cultural group selection in territorial lobstering in Maine. Sustain. Sci. 13, 21–34. https://doi.org/10.1007/s11625-017-0501-x

Waring, T., Kline, M., Brooks, J., Goff, S., Gowdy, J., Janssen, M., Smaldino, P., Jacquet, J., 2015a. A multilevel evolutionary framework for sustainability analysis. Ecol. Soc. 20. https://doi.org/10.5751/ES-07634-200234

Waring, T., Kline, M., Brooks, J., Goff, S., Gowdy, J., Janssen, M., Smaldino, P., Jacquet, J., 2015b. A multilevel evolutionary framework for sustainability analysis. Ecol. Soc. 20. https://doi.org/10.5751/ES-07634-200234

Waring, T., Lange, T., Chakraborty, S., 2021. Institutional adaptation in the evolution of the 'co-operative principles.' J. Evol. Econ. https://doi.org/10.1007/s00191-021-00738-3

Waring, T.M., Sullivan, A.V., Stapp, J.R., 2016. Campus prosociality as a sustainability indicator. Int. J. Sustain. High. Educ. 17, 895–916. https://doi.org/10.1108/IJSHE-05-2015-0091

Waring, T.M., Wood, Z.T., 2021. Long-term gene–culture coevolution and the human evolutionary transition. Proc. R. Soc. B Biol. Sci. 288, 20210538. https://doi.org/10.1098/rspb.2021.0538

Wilson, D.S., 2020. This View of Life: Completing the Darwinian Revolution. Knopf Doubleday Publishing Group.

Wilson, D.S., Philip, M.M., MacDonald, I.F., Atkins, P.W.B., Kniffin, K.M., 2020. Core design principles for nurturing organization-level selection. Sci. Rep. 10, 13989. https://doi.org/10.1038/s41598-020-70632-8

Yeh, D.J., Fogarty, L., Kandler, A., 2019. Cultural linkage: the influence of package transmission on cultural dynamics. Proc. R. Soc. B Biol. Sci. 286, 20191951. https://doi.org/10.1098/rspb.2019.1951

Zefferman, M.R., Mathew, S., 2015. An evolutionary theory of large-scale human warfare: Group-structured cultural selection. Evol. Anthropol. Issues News Rev. 24, 50–61. https://doi.org/10.1002/evan.21439