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Synthetic Biology and Biodiversity

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Abstract: Anthropogenic activities such as land usage, over-exploitation of natural resources, species introduction, climate change all have greatly impacted the Earth's ecosystem and biodiversity. Synthetic biology is advancing at a breakneck pace, with far-reaching ramifications for food security, agriculture, trade, health, etc affecting global biodiversity in numerous unknown ways. Depending on how they are built and targeted, synthetic biology applications have significant positive and negative consequences for biodiversity conservation. However, there is no consensus on the current state of synthetic biology and its implications for conservation, much alone the possibilities for future improvements. The potential advantages vary from the protection of vulnerable species to the development of synthetic substitutes for wildlife goods. Changes in the ecological functions of target organisms, as well as negative effects on the lives of indigenous and local populations who rely heavily on biodiversity, are examples of potential negative effects. There is an urgent need for authoritative action that may assist the conservation community, governments, and businesses in reaching an agreement on the hazards and potentially linked with synthetic biology and how they should be addressed. The application of synthetic biology must also be informed by case-by-case evaluations, guided by scientific facts, and decision-making must incorporate traditional knowledge, religious and ethical values.

Keywords: Synthetic Biology, biodiversity, food security, agriculture, trade, health

A brief introduction to Biodiversity

CBD (Convention on Biological Diversity) has defined Biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

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The global biodiversity of life on this planet is a huge repository of nucleic acids, proteins, cells, tissues and organisms creating food chains and servicing the environment. For example, material goods such as food, timber and medicines, key functions like flood management, temperature regulation, nutrient cycling, and nonmaterial advantages such as recreation. Biodiversity contributes to agriculture (Hooper *et al*, 2012), enables the carbon cycle, and sustains human health (Barton and Pretty, 2010). It provides resilience to environmental change and provides social and economic benefits (Nicola *et al*, 2009; TEEB, 2009).

Human activities have altered ecosystems (Foley *et al*, 2005), converting natural landscapes into cement jungles, introducing non-native species, and destroying wildlife (Kilpatrick *et al*, 2017). Though efforts are going on to restore this balance, yet biodiversity continues to decline at various rates across the planet.

The question is: which approach or combination of approaches is suitable to restore the ecological balance and enable sustainable economic development. Conservation is already a unifying discipline with efforts like strengthening protected areas, advancing state policy on natural resources and so on.

Potential impacts of synthetic biology on biodiversity (risk & rewards)

Synthetic biology can be defined as "a further development and new dimension of modern biotechnology that combines science, technology, and engineering to facilitate and accelerate the understanding, design, redesign, manufacture, and/or modification of genetic materials, living organisms, and biological systems," (according to the definition by UN CBD, 2017).

New technological advancements have increased the possibility of using Synthetic Biology towards ecological conservation, complementing and reinforcing existing conservation techniques. New synthetic biology-based technologies may be capable of decreasing biodiversity loss by minimising the effects of anthropogenic hazards. For instance, it may reduce the hazards caused due to habitat destruction. The sea and land habitats are not available to wildlife due to the commercial utilisation of such areas by humans. For example, the area invested for energy installations can be saved by using alternative sources of energy such as microbial fuel cells (Redford *et al*, 2014).

The undeniable fact is that emerging capabilities of synthetic biology, when used for biodiversity conservation, have the capabilities to transform the conservation sector in unforeseen ways, either good or bad, and over unpredictable timescales.

Of the 170 animal extinctions, invasive alien species are responsible for 20% (solely) and 54% (partly) (Clavero and García-Berthou, 2005). Invasive alien species have largely affected about 1352 amphibians, reptiles, birds and mammal species worldwide (Bellard *et al*, 2016). Synthetic biology offers ingenious alternatives against invasive alien species as well as eradication of new alien invasive species which may pose risk to biodiversity. The consequent profile whether helpful or deleterious of anticipated synthetic biology techniques applied for control of "invasive alien species" will thus be variable depending on targeted species or population, purpose and application scale.

Invasive species control. Gene drive is a process in which a gene has a property to be transmitted at a frequency even higher than the typical 50 per cent by replicating itself as well as selectively eradicating competing elements (Burt and Trivers, 2009; Marshall, 2009). This results in the spread of gene drive elements across populations even if the individuals carrying the elements do not benefit from a fitness advantage, while a fitness penalty will delay and perhaps block spread. Many distinct forms of gene drive may be found in nature. Certain gene drive elements, both natural and manufactured, are projected to spread to the majority of target animal populations (Noble *et al*, 2018; Hoffman *et al*, 2011). Other gene drive systems are naturally limited owing to frequency dependence; intended local drive systems, like non-driving genes, are not anticipated to propagate much beyond the targeted populations (Marshall and Hay, 2012; Basalova *et al*, 2018). Scientists want to harness gene drive by either exploiting naturally existing systems or by synthesizing synthetic analogues known as "engineered gene drives," which might be exploited to propagate engineered alterations across many generations of wild populations Teem *et al*, 2020). Some invasive species control tactics may allow invasive species populations to be decreased by restricting the fertility of organisms inheriting two altered copies or by changing the sex ratio (IUCN SSC, 2016).

Restoration of extinct species. Some synthetic biology applications in conservation have been grabbing eyeballs. For instance, "de-extinction" – an act of generating an organism that is once an extinct species or acts as a substitute restoring the ecological value of their extinct counterparts – (IUCN SSC, 2016). The application of synthetic biology-based tools to restore extinct species is an intriguing concept that has captured the public interest. Additionally, media interest in resurrecting extinct species such as mammoths, top-level events and channels (e.g., National Geographic, TEDx,), and well-funded projects like the passenger pigeon project[1] added more curiosity and derived lots of attraction towards the topic. It is quite probable that some of these projects will be executed since the efforts will draw financing, and serve as an example of synthetic species made on public demands. It is feasible that a market centred on the public display of lost species will arise, either in the private sector (amusement parks like "Jurassic Parks") or as commercial zoos. The appeal of species restoration for conservation purposes may be obvious, but there are compelling reasons to be worried about. For instance, in quest of generating an ultimate "diva species" (Sandbrook, 2012), de-extinction may take funds diverted from other more important conservation issues as well as may lead to other unknown long-term consequences (Novak, 2018). Thus, extinction may no longer be permanent considering ongoing efforts of rebuilding endangered species using synthetic biology technologies. Woolly mammoths, passenger pigeons, and thylacines are among them. Such experiments are going to be very highly expensive, but as predictions suggest prices may fall in future and such restoration and re-creations may become ubiquitous and economically viable. But again, the most important questions remain unanswered: if the resurrection of extinct species become successful, will such species be referred to as a substitute for extinct forefather's species or they may become invasives from the past posing threat to present species. On what grounds, decisions will be made about which species is to be saved or restored and which not. What will be the consequence of restoring extinct species if the ecosystem formerly housing them no longer exist? What if our efforts to protect naturally occurring biodiversity are compromised in course of resurrecting extinct species (Norton, 2010).

Disease resistance. Talking on chronic threats, Synthetic biology might potentially give possibilities for engineering resistance to fungal infections, which are currently posing a danger to a variety of species and plants (Fisher *et al*, 2012) such as, bats found in North America are highly infected with "white-nose syndrome", an illness caused by a fungus (White-nose Syndrome). Being insectivorous and aiding in plant fertilisation, bats are projected to provide USD 23 billion to US farmers each year (Gruner, 2013).The mass killing of bats has greatly impacted agriculture. Reduction or eradication of the impact of the white-nose syndrome would benefit both biodiversity and human wellbeing. Synthetic biology could be utilized to counteract the given problem by either attacking the disease-causing fungus or interfering with its mode of infection. Certain applications, such as the engineering of microorganisms to biosynthesize chemicals supplied from imperilled species. For example, a therapeutically useful molecule isolated from the horseshoe crab's blood, are already in the works (Maloney, Phelen and Simmons, 2018).

Habitat restoration. Synthetic biology is able to actively help in habitat restoration, particularly by removing contaminants, eliminating invasive diseases or competitive species, or increasing decomposition rates (Kumar and Singh, 2020). However, the concept of restoration must be carefully managed so that it does not undermine people's enthusiasm to protect the ecosystems (Caro *et al*, 2012). Biological clean-up of the Gulf of Mexico oil spill (2010) occurred faster than planned, but the large deep-water leak caused significant and ongoing harm (Redford *et al*, 2019). To assist in the management of such disasters, it is plausible to imagine employing synthetic biology to generate and alter microorganisms with greater capacity to digest spilled hydrocarbons.

The beliefs that underpin public debate over the utilisation of synthetic biology-based products raise several social, philosophical, ethical, political and moral concerns. One recurring concern is that interventions of synthetic biology are comparable to "playing God" (Dabrock, 2009; Heather *et al*, 2017), including actions which ought not to be taken either because of the threat of irreversibly disrupting complex natural systems which are currently beyond humanity's control or because of one's own faith and values. Such values are likely most visible when it comes to concerns of species extinction (Sandler, 2012). This is especially significant for problems concerning the construction of substitutes for extinct species (IUCN, 2016). De-extinction has been called “a fascinating but dumb idea” since it has the potential to draw resources away from endangered species conservation.

Some scientists and ethicists recommend a utilitarian approach to synthetic biology in which ethical concerns about the use of synthetic biology are weighed against the potential benefits to humanity (Smith, 2013). In the instance of employing a gene drive to combat malaria, for example, ethicists balanced the moral grounds against changing a mosquito species against the moral justifications for inventing a new instrument that may lower clinical malarial illness caseloads (Zoloth, 2016).

It is not difficult to envisage several conservation problems associated with the use of synthetic biology technology. These include new creatures escaping from confinement and establishing themselves in open environments. Such species (eg: derived from recombinant DNA technology, synthetic biology, or conventional breeding will possibly alter existing ecosystems negatively and if they transfer genetic material with wild species, they will change the existing biodiversity via decreasing viability (Ket *et al*, 2008). There’s also a chance that these new synthetic biology derived organisms will become invasive, competing or replacing current species that will imposes a particular risk to species that are endangered or rare (Jeschke *et al*, 2013);. Hybrids and transgenics that has been developed from genetic combinations with their wild types (e.g., genetically modified Atlantic salmon) (Oke *et al*, 2013). Such risks are also associated with the introduction of novel species for conservation reasons (e.g., to aid in the restoration of contaminated or damaged ecosystems), and these scenarios will necessitate thorough investigation and analysis, as well as a careful balance of potential risks versus gains.

Convention on Biological Diversity

The advancements in synthetic biology, like in other science and technology governance systems, is influenced by discussion at international, national, and private-sector-driven perspectives and interests. Several worldwide, legally enforceable environmental conventions and treaties that give direction on the fate of technological developments like synthetic biology must be considered by nations. Several international processes are now examining possibilities for dealing with synthetic biology products and organism development and deployment.

Several international organisations and treaties are now investigating the effects of synthetic biology technologies and products on their respective agreements. The need to limit the human effect on biological diversity has gained widespread political support. The "United Nations Convention on Biological Diversity" (CBD), is one of the world's most frequently recognised treaties. Since 2002, 196 nations CBD parties have pledged that by 2010 the rate of biodiversity loss needs to reduced significantly; To facilitate its work, the parties agreed to form an "Ad Hoc Technical Expert Group" (AHTEG) and organise a monitored, open-ended online discussion. The AHTEG has developed an integrative framework for synthetic biology, which will serve as a good starting point for future discussion. Parties agreed that frequent horizon-scanning of the most current technological breakthroughs is necessary for analysing new information on synthetic biology's possible impacts. There is a growing number of international, national and regional policy frameworks that target biodiversity conservation; such as, 87 per cent of CBD signatories have now developed on "National Biodiversity Strategies" and "Action Plans", providing strategies for addressing biodiversity loss at the national level[7]. The method is specifically applied to synthetic biology in CBD COP Decision XI/11, which states:

> *"Recognising the development of technologies associated with synthetic biology, synthetic cells or genomes, and the scientific uncertainties of their potential impact on the conservation and sustainable use of biological diversity urges Parties and invites other Governments to take a precautionary approach, under the preamble of the Convention and with Article 14, when addressing threats of significant reduction or loss of biological diversity posed by organisms, components and products resulting from synthetic biology, following domestic legislation and other relevant international obligations."*

Case by case risk assessment and monitoring regimes

Synthetic biology applications for products and organism developments are subject to case by case or staged monitoring and control at various levels, ranging from the laboratory scale to field trials or organism's deployments.

The CBD COP14 expanded the AHTEG and emphasised the importance of case-by-case risk evaluations before organisms harbouring modified gene drives are released into the environment, as well as the possibility of comprehensive risk assessment recommendations. [COP/14/L.31 para 9(a), 10].

The risk assessment approach has a basic framework across nations but varies slightly concerning depth and breadth of study (Claudia *et al,* 2008) . The EU Environmental Risk Assessment approach is one of the most extensive examples. The majority of risk evaluation approaches are relying on two basic components: (1) Assesments of planned and unintentional consequences, including the likelihood and possible importance of the impacts; and (2) Comparison of the changed product with current equivalents (Claudia *et al,* 2008). When analysing prospective consequences, decision-makers may consider information on gene transfer, persistence, and toxicity, as well as possible intended and unforeseen effects on targeted and nontargeted populations, as well as respective socio-cultural implications[28].

Legislation may provide provisions for monitoring regulated activity. Multiple authorities in the United States have post-market monitoring power over biotechnology goods. The FDA mandates producers to disclose and conduct market risk analysis and safety assessments on foods, pharmaceuticals and biotechnology goods (NASEM, 2017). The EPA is obligated for re-evaluation of pesticides in every 15 years, but in fact, it has only done so every 5–6 years. Genetically modified organisms that potentially behave as plant pests are possibly deregulated in this case minimal monitoring or supervision is required (NASEM, 2017).

Systems biology, molecular biology, bioinformatics, plant virology and microbial ecology are all areas related to synthetic biology that comes under one umbrella. When conservation is concerned, each product, tool, and technique produced from the fields of synthetic biology needs to be assessed based on the evidence of the negative and positive consequences they are anticipated to have on any particular conservation target. In all circumstances, the evolutionist must thoroughly evaluate the impact of the synthetic biology method on the whole spectrum of conservation goals for all affected species. Only then may well-informed choices be made. Such studies would compile a knowledge base to aid decision-makers in understanding the vast range of synthetic biology applications available, as well as the considerations that should be made concerning their impact on the conservation of biodiversity.

Environmental governance is riddled with scientific ambiguity. The precautionary method, often known as the precautionary principle, is a decision-making technique for dealing with uncertainty (Peterson, 2006; Wiener and Rogers, 2002). According to the Rio Declaration, "when there are concerns of significant or permanent harm, lack of complete scientific knowledge must not be used as a justification for delaying cost-effective steps to avert environmental deterioration." [Principle 15 of the Rio Declaration]

Synthetic biology applications include the risk that is unclear and potentially unratifiable, necessitating the use of the precautionary approach or methodology. There is no agreement on what this entails with respect to regulatory actions. Some supporters of synthetic biology argue that certain or all of the new technologies needs to be free from present GMO regulation, Others say that all methods should be subject to executive monitoring, which might lead to certain procedures being streamlined. (ENSSER, 2017). According to certain social and scientific organisations, the precautionary approach or strategy mandate a "moratorium on the release and commercial usage of synthetic organisms, cells, and tissues." Others contend that a synthetic biology moratorium will damage the field and stifle potentially positive developments, but a more nuanced understanding of the concept that allows for limited, well-regulated risk might assist to manage the conflict between a need for caution about intervention risks and worry about non-intervention hazards (Wareham and Nardini, 2015).

Different methods are used by national regulatory regimes for addressing the extent of application. These techniques are frequently described in terms of "product" or "process" principles. A "product" method means that supervision is triggered by particular qualities of goods that are regarded to be risky, regardless of how they were created, whereas a "process" method means that the goods that are subject to supervision are described by the process by which it was generated (Kuzma, 2016). In practice, product-based regulatory methods frequently rely on process-based distinctions, whereas process approaches frequently evaluate a combination of "product and process" based characteristics (Bergeson, Dolan and Engler, 2015).

Under the Plant Protection Act (PPA), the Federal Insecticide, Fungicide, and Rodenticide Act, the Toxic Substances Control Act, the Federal Food, Drug, and Cosmetics Act. the United States employs what is commonly referred to as a product approach ((Bergeson, Dolan and Engler, 2015). However, in rare circumstances, authorities may consider procedure while making decisions. Applications for licences to introduce genetically engineered plant pests, for example, need a full explanation of biology of the system at the molecular level (e.g., donor-recipient-vector) that will be employed to create the regulated commodity" [US 7 CFR 340].4] (Keiper and Atanassova, 2020).

Conservation and sustainable use of biodiversity

Synthetic biology offers both potential advantages and drawbacks that might impact resource management and economic growth today and, in the future. The sustainable development is defined as "the development that meets the demands of the present without jeopardising future generations" and ability to satisfy their own needs" (WCED, 1987). It recognises the interdependence of economical and societal growth and environmental protection (Rio Declaration, Principle 4).

Discussing the possible consequences of synthetic biology for biological diversity conservation and sustainable usage requires a review of current policy frameworks and the specific governance difficulties posed by synthetic biologies, such as designed gene drive technology (Kumar, 2012).

Several synthetic biology applications are designed to give a path to achieving sustainable development goals. Such as applications addressing "invasive species" could help to achieve the goals of conservation of terrestrial and marine biodiversity [SDGs 14 and 15], whereas some synthetic biology applications which address vectors that cause diseases in humans such as "mosquitos" help to achieve the goals related to human health and as well as poverty alleviation [SDGs 1 and 3]. Simultaneously, some of the hazards connected with synthetic biology may have a different impact on achieving these aims.

Civil societies, conservationists, synthetic biologists under one umbrella

Now is the moment to assess if synthetic biology is an evil solution, causing its issues, some of them may be undesired or even unacceptable in terms of conservation of biodiversity.

Extinction may not be permanent if synthetic biologists and others scientists follow their proposals to utilise modern genetic-engineering technologies such as genome engineering to preserve endangered species and bring extinct ones back to life (Piaggio *et al*, 2017). This is the most apparent example of a broad collaboration between the synthetic biologist and the biodiversity conservationist that should take place. The broad collaboration between the synthetic biologist and the biodiversity conservationist has the potential to transform the connection between people and the natural world.

Currently, synthetic biology and the biodiversity conservation have progressed individually. The experts and the scientists that practise them differ not just in apparent aspects, such as scientific practise and training, but also in subtle ways, such as world views, attitudes to risk and uncertainity, and value systems. Despite these contrasts, there is a growing feeling that synthetic biology and conservation will merge, or, as some fear, clash, in the coming years. New approaches to apparently intractable issues using scalable technology provide a slew of new and unexpected obstacles. It is widely acknowledged that an established and active discussion may limit the potential risk of synthetic biology products being created for diverse objectives and maximise their value for nature conservation (Marris and Jefferson, 2013).

Synthetic biology's emergence has sparked debate among conservationists throughout the world, as well as a emerging recognition of the importance of detailed and more significant collaboration between current synthetic biology and conservation organisations (Garfinkel *et al*, 2007) .

Many developing-country governments, native leaders, and regional groups have also expressed worry about how synthetic biology emergence may harm their traditions, rights, and livings. The optimism and scepticism around the use of synthetic biology in conservation are concerned because biodiversity loss continues although having the sophisticated framework of conservation science and policy; and the realisation by all levels of government organisations, and the society, that human well-being is dependent on a healthy natural environment.

Decision making and regulations

Good governance procedures apply to “decision-making” that affects or may influence wildlife and the natural habitat. “Access to information”, “public participation” in decision-making, and “access to justice” are three critical components of good governance procedural rules. (SDG 16; Rio Declaration Principle 10).

Synthetic biology decision-making may jeopardise native peoples and the community’s rights to natural resources and culture. The right to manage natural resources and wealth is included in the notion of people’s self-determination, which is recognised in the “United Nations Charter”, the “International Covenant on Economic”, “International Covenant on Civil and Social, and Cultural Rights”. (UN Charter art. 55; ICCPR art. 1; ICESCR art. 1).

According to AHTEG, the development of synthetic biology techniques and applications must be complemented by the effective engagement of native peoples and local communities. In 2018, the CBD COP urged Parties and other government organisations to obtain consent or approval, that should be, free, prior informed, as well as the participation of potentially affected indigenous peoples and local communities before implementation of engineered gene drives into the field (COP/14/L.31 para. 9, 11).

The confinement of modified organisms is a crucial issue for the conservation of biological diversity. Existing ‘laboratory’ and ‘field’ classifications are ambiguous and may preclude the safety of new and existing species. There is knowledge of invasive species that can be applied to new creatures. It may be feasible to build genetic technology to prevent synthetic creatures from escaping inadvertently. At the same time some applications such as white-nose syndrome or environmental clean-up, necessitate the spread of new species rather than their confinement. In circumstances like these, how might safety considerations be incorporated? (Dudley, 2011).

The significance of public opinions and comprehension cannot be overstated. The degree of public acceptance in synthetic biology solutions for biodiversity conservation will influence the policies, financing, and regulatory frameworks. We must think carefully about how problems, risks and rewards are portrayed in the media, and we should consider cooperation with communication specialists and social scientists to understand and articulate from diverse points of view, as well as to help in developing effective narratives. The majority of media coverage on synthetic biology and biodiversity is currently influenced by sensational headlines of endangerment and extinctions, disregarding the potential benefits of synthetic biology in addressing conservation issues, and largely avoiding the governance, moral, and social issues that required discussions (Novossiolova, 2016).

New cooperative studies between research scholars, civilians, and other sectors of society are required to overcome the information shortages and the differences between how practitioners in the two professions think today. Perhaps properly planned and controlled experimental work might help us to gain a better grasp on the use of synthetic biology for conservational purposes. Such projects might help to strengthen personal and disciplinary bonds, as well as provide ideas for adjusting to a changing climate.

The evolution of synthetic life is underway. The rapid emergence of synthetic life arises several questions such as ; How will synthetic life interact with the natural one, and how well can such interactions anticipate using present ecological knowledge of interspecies interactions? or will they be safe and utilised for repairing damaged or polluted habitats or solving other ecological and environmental problems that have previously proved difficult to solve? Is it possible that the introduction of synthetic organisms into ecosystems would have a beneficial effect? Will they be evaluated as having higher value if they increase the living variety of the ecosystems in which they are embedded, or will they be judged as degraded if they lose their authenticity (Kaebnick, 2011)? Will the "garage biology" regulatory environment be generally approved, or will national governments attempt to build separate regimes, and how will national and international perspectives on the issue be considered (Schmidt, 2010)?

The definition of "natural" as we know it now is no longer valid. Mostly conservation is dependent on preserving ecosystems that have evolved through time via evolution and ecological successions, sometimes revealing intricate webs of interdependence that are difficult to recover if broken. Will the interactions between synthetic organisms/cells with their natural counterpart to be easy to form, or may their very different origins have a big influence on natural communities? What influence would this have on common perceptions of "natural," and the concept of evolution as a process regardless of human creation? Will new technologies, as in other contexts, call into question the ethical concern for conservation ((Kaebnick, 2011)? How will we assess organisms developed through unique nucleotides as a part of their genetic code "xenobiology products"? (Schmidt, 2010.

Conclusion

Several synthetic biology technologies and applications, if properly designed and well addressed, can benefit the conservation of biological diversity. The majority of technological advancements attempts have been taken to eliminate or suppress invasive alien species. To date, no design or technology is ready for field trials or implementation for biodiversity conservation. The field's applicability and effectiveness of proposed synthetic biology technologies are anticipated to face several challenges that will need more study, or may even prove to be insurmountable obstacles for beneficial applications. Any proposed trial designs and field sites should be evaluated based on every different case. Gaining a better understanding of stakeholder interests concerning any potent application and product of synthetic biology for conservation would need social science research and stakeholder interaction. Humanity should bear the responsibility of decreasing the rate of biodiversity loss. Integrated strategies are required for this. It's high time for conservationists to think about the aplications of synthetic biology and other new genetic technologies. Engagement is critical, and should be founded on a set of guiding principles and a solid decision-making framework to comprehend the advantages and drawbacks based on existing and emerging information to maximise biodiversity benefits while minimising biodiversity loss. The conservationists should seek out synthetic biologists, and the two should collaborate on broad discussions with scientists, communities, and regulatory bodies throughout the world. Our efforts at this critical intersection of biodiversity protection and technology might determine the destiny of nature.

Endnote

[1] Revive & restore. 2013. Http://longnow.org/revive

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