

Strange Natures: Conservation in the Era of Synthetic Biology
by **Kent H. Redford and William M. Adams**

A Study Guide for Lecturers and Students

These questions are designed to be used as a basis for discussion by students studying synthetic biology and conservation on Undergraduate and Masters programs. Relevant courses include: *Conservation Biology; Ecology, Environmental Ethics; Environmental Science, Environmental Management; Geography, Genetics, History of Science; Science and Society; Science and Technology Studies; Wildlife Management.*

Chapter One: The Place of Nature

1. Where can nature be found? What is the place closest to you where you would look for it?
2. Does nature exist in agricultural fields, and if so does their naturalness change depending on how those fields are managed and what crops are grown in them?
3. In what ways is the story of Frankenstein relevant to discussions of what is natural, or human feelings about technology?

Chapter Two: The Problem of Nature

1. How much artificiality is okay for conservationists to use to protect nature? Can you think of examples of things done in conservation that feel ‘unnatural’?
2. To what extent is it possible to distinguish between what is ‘natural’ and what is ‘artificial’? Do you think that one is better than the other?
3. Does what is considered natural vary between cultures and countries, and over time? If so how should this affect the way we think about the conservation of nature?
4. If ecosystems are constantly changing, what does it mean to restore nature? Do forms of restored nature have to be exactly the same as what was lost?
5. Can novel ecosystems have a value for conservation, and should we think of them as natural?

Chapter Three: Nature’s Diversity

1. Why is the diversity of nature important? Do we need to be able to identify species in order to be able to conserve them?
2. How much do you think a conservationist needs to know about genetics?
3. Where does the diversity of nature come from?
4. How significant for conservation is the scientific ability to map the genomes of species?

Chapter Four: Conserving the Genetic Pieces

1. If the species is a human-designated category, what implications does this have for the conservation of nature?
2. What reasons might be given for and against importing Texan pumas to interbreed with pumas in Florida? Do other examples of attempts to manage the genomes of wild species offer useful lessons for conservation?
3. In what ways might the microbiome be important in conservation?
4. How do humans affect the evolution of wild species, and do these influences matter?

Chapter Five: Rewiring Nature

1. Is it possible to create artificial life or a new species? If so, how should taxonomists classify such novel entities, and how should conservationists think about them?
2. Why is there no internationally agreed definition of synthetic biology, and does this lack of a standard definition matter?
3. Should we understand gene editing as simply an extension of previous techniques of genetic modification, or as something quite different?
4. Should we understand the techniques of synthetic biology (such as gene editing) as simply an extension of the long human history of domesticating plants and animals or as something new and different?
5. How significant is the distinction between “cis-genesis” (the introduction of genes from another variety of the same species (or a closely related species), and “transgenesis” (the transfer of genes across species boundaries) in assessing the applications of genetic engineering?
6. Synthetic biology’s desire to automate experimentation and engineering of genomes using the “design-build-test-learn” cycle is proving very powerful. How should we think about it?
7. How should conservationists respond to synthetic biology’s capacity to fabricate genetic parts and systems that do not exist in the natural world or redesign and rebuild those that do?

Chapter Six: Synthesizing the World

1. Do you agree with the idea that the ability to engineer the genomes of living organisms provides the basis of a “fourth industrial revolution”? If so, do you think all of humanity will benefit from this revolution?
2. Should the idea of “DIY biology” or “garage biology” make us excited or apprehensive?
3. Should it be possible to patent the genetic information contained in the genomes of wild species, or should this be regarded as an open-access public resource?
4. Discuss possible arguments for and against the use of engineered gene drives in human health or agriculture.
5. Should products made using synthetic biology technologies be labeled for consumers?

Chapter Seven: Genetic Technologies in Conservation

1. How would you weigh up arguments for and against the release of varieties of American chestnut that have been genetically engineered to be resistant to the chestnut blight fungus.
2. In what ways does synthetic biology offer improvements over other techniques for controlling invasive species and wildlife disease?
3. In what circumstances should conservationists be most concerned about the ecological effects of the deployment of gene drives in wild species?
4. To what extent might synthetic biology techniques contribute to reducing human transformation of the Biosphere in the Anthropocene?
5. To what extent do you think that de-extinction will make a major contribution to future biodiversity conservation? If a species were to be brought back from extinction, which species would you choose, and why?

Chapter Eight: Nature's Future

1. To what extent does the language used to describe novel technologies (by those opposing their use and supporting it) affect the way we think about them? Does science fiction help or harm our understanding of the new technologies?
2. Do you think that the release of organisms engineered by synthetic biology should be regulated in the same way as GMOs (genetically modified organisms), or treated differently?
3. Should the genetic engineering of wild species be subject to the same rules as domesticated species, or treated differently?
4. Who should be empowered to make decisions about the release of engineered wild organisms? To what extent can the views of the public be taken into account in making such decisions?
5. How do you think the risks posed by novel technologies, and uncertainty about those risks, should be addressed? What do you think are the strengths and weaknesses of the 'Precautionary Principle'?

Chapter Nine: Conserving Strange Natures

1. If independence from human intervention is an important element in the value of nature, do you think that genetic engineering, and the human design and control it involves, undermine that value?
2. Do you think synthetic biology raises significant issues relating to the naturalness or authenticity of species whose genomes have been re-engineered?
3. Should changes to the genomes of wild species made using synthetic biology techniques be viewed differently from those resulting from evolution associated with other human activities like city lighting or hunting?
4. How useful is a black and white distinction between "natural" and "artificial" at the level of the genome in our human-dominated world?