Nanotechnology, Enhancement, and Human Nature

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Abstract Is nanotechnology-based human enhancement morally permissible? One reason to question such enhancement stems from a concern for preserving our species. It is harder than one might think, however, to explain what could be wrong with altering our own species. One possibility is to turn to the environmental ethics literature. Perhaps some of the arguments for preserving other species can be applied against nanotechnology-based human enhancements that alter human nature. This paper critically examines the case for using two of the strongest arguments in the environmental ethics literature to show that nanotechnology-based human enhancements are impermissible: 1) Our species, like many other naturally occurring species, has aesthetic value. So, nanotechnology-based human enhancements that alter our species should be prohibited. 2) Our species plays valuable ecological roles. Nanotechnology-based human enhancements that alter our species are likely to interfere with our species playing our ecologically valuable roles. So, such enhancements should be prohibited. Neither argument, ultimately, proves conclusive. The paper concludes, however, that considerations underlying both arguments may show us that some nanotechnology-based human enhancements are impermissible.

Keywords Nanoethics · Nanotechnology · Enhancement · Species · Ecosystem · Evolution · Human nature

We can no longer assume that there will be a single successor to what has been regarded as human nature. We must consider the possibility that at some point in the future, different groups of human beings may follow divergent paths of development... If this occurs, there will be different groups of beings, each with its own “nature,” related to one another only through a common ancestor (the human race), just as there are now different species of animals who evolved from common ancestors through random mutation and natural selection [19, p. 95].

Introduction

The *Proceedings of the National Academy of Sciences* recently reported that nanotechnology may provide alternatives to viral transfection, or gene transfer, bringing humanity one step closer to successful human enhancement [6]. Nanotechnology-based human enhancement might eventually change or even eliminate our species.¹ Many people find this possibility disturbing. It is harder than one might think, however, to account for the value of our species. And, it is harder to explain, than one might imagine, what could be wrong with altering our species. The most

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¹ On human enhancement see [57].

common arguments against nanotechnology-based human enhancement are anthropocentric and individualistic, appealing to the importance of *individual humans'* interests, welfare, or autonomy. But there is reason to question many of these arguments [37, 49]. So there is reason to consider whether arguments that (also) appeal to other ethical perspectives, (e.g. non-anthropocentric, non-individualistic arguments), can provide reasons to reject nanotechnology-based human enhancement.² Furthermore, there are independent reasons to consider such pluralistic arguments. Arguments against nano-enhancement, if they are successful, would provide reason to create a policy prohibiting such enhancement. Pluralistic arguments might form the basis of an over-lapping consensus on policy [64].^{3,4} Hence, this paper will consider analogues to arguments for preserving other species in the environmental ethics literature. For, many of these arguments can appeal to those who care about non-human species and individuals or even ecosystems and the biosphere, as well as those who only care about human individuals.

Setting border-line cases aside, there are three broad kinds of arguments for preserving species—those that appeal to a species' instrumental value, those that appeal to a species' non-instrumental value, and those that appeal to the value of our species' acting as a caretaker or steward for endangered species [68]. It is not clear, however, why our acting as a caretaker or steward should have value unless it is because the species we are aiming to preserve has value. And, I cannot see how one might fruitfully argue that we ought to preserve our species because the role of preserving our species is valuable. So, this paper critically examines two arguments that can be understood as citing the intrinsic or instrumental value of our species as a reason for

preservation.⁵ In particular, it considers the case for using two of the strongest arguments in the environmental ethics literature for preserving species to show that nanotechnology-based human enhancements are impermissible.⁶ First, our species, like many other naturally occurring species, has aesthetic value. So, nanotechnology-based human enhancements that alter our species should be prohibited. Second, our species plays valuable ecological roles. Nanotechnology-based human enhancements that alter our species are likely to interfere with our species playing these roles. So, such enhancements should be prohibited.

Although neither the aesthetic nor ecological role argument against nanotechnology-based human enhancement ultimately proves conclusive, they fail in noteworthy ways. In light of the environmental destruction our species causes, one might think it obvious, for instance, that our species does not play many valuable ecological roles. This paper argues, however, that this is not so clear. Rather, the arguments have similar problems; our unenhanced species' value might not be threatened by enhancement and, even if it is, our value may not trump the value of enhanced species. Enhanced species may even have more value than our unenhanced species. Neither of these arguments goes through. They are based on some of the strongest arguments for preserving species in the environmental ethics literature. So, the paper concludes, the prospect for using this literature to show that nanotechnology-based human enhancements are impermissible is dim.⁷ This paper suggests, however, that we can learn a lot by considering the environmental ethics literature in the debate about nanotechnology-based human enhancements. Considerations underlying both of the arguments we

² These arguments may also provide reason to question other human enhancements, tools, natural aids, and even treatments for serious diseases. This essay will only consider whether a concern for preserving our species gives us reason to question nanotechnology-based human enhancements, however.

³ For analogues to the arguments we will consider see, for instance [27] and [34].

⁴ I know of no one who has considered analogues to arguments for preserving other species. Perhaps this is because many of these arguments assume that there is reason to preserve our species. They then try to show that there are no relevant differences between those species and ours. At least most individualist arguments are of this type—for instance, animal rights arguments often specify that non-human animals are relevantly similar to human animals and so deserve protection [58].

⁵ On life's intrinsic value see [1].

⁶ Lilly-Marlene Russow in "Why do Species Matter?" suggests that aesthetic value is the best way of explaining species' non-instrumental value and seems to think that the strongest version of the instrumental value argument will appeal to species' roles [68, 140–142]. This paper will discuss below, however, how both of the arguments it will consider can be given instrumental and non-instrumental readings.

⁷ There are other reasons to consider whether other arguments for preserving species from the environmental ethics literature can give us reason to reject nanotechnology-based human enhancement as well. This inquiry may teach us something about the prospects for using such arguments to show that it is impermissible to alter species quite generally. Similar lines of reasoning to those pursued here may, for instance, pose problems for those who want to use aesthetic or ecological role arguments against altering other species.

will examine may, for instance, show us that *some* such enhancements are impermissible. Before turning to these arguments, however, consider the nature of nanotechnology-based human enhancement.

Nanotechnology-Based Human Enhancements

Nanomaterials are generally defined as materials smaller than 100 nm. They are found in every thing from tires, bikes, and sunscreen to submarines [38]. Nanotechnologies are technologies that utilize, rely upon, or produce these materials. As with recombinant DNA, radioactivity, and chlorofluorocarbons nanomaterials have revolutionary potential. For instance, scientists are developing artificial muscles with carbon nanotubes, nanoparticles that bind to red blood cells to help with drug delivery, and nanoparticle based gene transfer technology [5, 18, 29, 33, 79].

Some of the potential uses of nanotechnology constitute treatments and others constitute enhancements. Very roughly, a treatment aims to ameliorate a disease or the effect of a disease, where a disease “consists of conditions that are adverse departures from normal species functioning” [10, p. 72]. Enhancements aim to bring beneficial “departures from normal species functioning” [10, p. 72]. If, for instance, carbon nanotube based artificial muscles are used to improve athletic performance, they constitute enhancements. Nanotechnology-based gene transfer used to cure a terrible disease like Tay-Sachs would, on the other hand, constitute a treatment. If, instead, carbon nanotube based artificial muscles are used to help those with polio, while nanotechnology-based gene transfer is used to improve memory or strength, nanotube based artificial muscles would constitute a treatment, while nanotechnology-based gene transfer would constitute an enhancement. Some modifications may be both treatments and enhancements, however. Suppose, for instance, that nanotechnology yields a drug that improves immune function and makes it easier for people to fight AIDS. The drug may constitute both an enhancement and a treatment.⁸ It may help treat

AIDS victims and generally enhance individuals’ ability to fight infection.

Even setting such mixed cases aside, the treatment/enhancement distinction is hard to draw precisely [20, 43]. There are many ways of explaining what constitutes *normal functioning*⁹ and many definitions of *species*.¹⁰ Considering the intricacies of the different definitions will take us too far a-field, however. Because good definitions of *normal species functioning* must yield intuitive judgments about what constitutes enhancement in most cases, we can, instead, proceed with an intuitive understanding of *normal species functioning*. We must simply reserve

⁹ One way of thinking about normal functioning is as a purely statistical concept. On the statistical concept, something functions normally when it functions at modal or mean levels. Another way of thinking about normal functioning is as a biological concept [40, 50]. Just as we can say the human heart functions normally when it circulates blood, we can say a species functions normally when it fulfills the potential inherent in its biological inheritance [81]. The biological conception of normal functioning is different from the statistical conception in that it does not refer to the way most members of a population function. One should be careful, however, not to confuse normal functioning with ideal functioning, on the biological conception. A member of a species need not function perfectly to be normal any more than it need function in exactly the same way the modal member of that species functions. There are, of course, other conceptions of normal functioning, and different conceptions of normal functioning may be better and worse for different purposes [32, 44].

¹⁰ On the most common definition, a species is a group of individuals that are normally capable of reproducing at maturity producing fertile offspring [10, 82]. Alternate definitions refer to similarity between the genetic, behavioral, historical, or morphological characteristics of individuals or populations. For instance, on some historical definitions species are just the least inclusive taxonomic groups in a phylogenetic classification; on this phylogenetic species concept, a species is distinguished by its members sharing a single common ancestor [56, 63]. There are problems with all of the going definitions. It is hard, for instance, to set out precise criteria for when individuals are capable of reproducing. Suppose, for instance, that canines from two groups that do not normally inter-breed are forced to do so and produce fertile offspring. Are the two groups capable of interbreeding? What if the only way the canines could interbreed is with the assistance of some intermediating technology (e.g. in-vitro fertilization)? Similar problems arise for other definitions of species [24]. The different definitions also yield different conclusions about what species exist in some cases [24].

⁸ Most enhancements are not mere tools or natural aids [49]. A hammer, for instance, is not an enhancement. Nor are natural aids like a good diet enhancements, though both external tools and natural aids can bring beneficial departures from normal species functioning.

judgment about whether the arguments below will apply to borderline cases.¹¹

Even without settling on a particular definition of *normal species functioning*, it should be clear that, over time, nanotechnology-based human enhancement may alter our species. The most obvious way that this could happen is if nanotechnology-based human enhancement sufficiently altered the genetic code of some individuals. Alternately, some individuals might reject or insist on breeding partners with enhancements. So, over time, nanotechnology-based human enhancement might cause different groups of individuals to take different evolutionary paths. Finally, nanotechnology-based human enhancements might even eliminate our species if, for instance, such enhancements changed everyone's genetic code sufficiently. Our species will almost certainly be altered or go out of existence at some point even without nanotechnology-based human enhancement. Other technologies, from tractors and the printing press to computers and the internet, have altered and will probably continue to alter our species. Nanotechnology-based human enhancement might, however, change our species in novel ways. Such enhancement might greatly prolong our lives or allow us to survive more easily in extreme climates. Alternately, this enhancement might change our species much more quickly than we would otherwise change. Even if such enhancement does not alter our species, however, thinking about the possibility gives us the opportunity to consider what we should say about our species changing for other reasons.¹²

¹¹ Normal species functioning may change over time. If such functioning is a statistical concept, for instance, tools and natural aids may (just like natural selection) change the baseline for normal species functioning eventually. For instance, better diets, medicines, and sanitation have all decreased the incidence of disease and increased the average life span, so may have changed normal species functioning. Nanotechnology-based human enhancements might eventually change the way species function as well. If so, nanotechnology-based human enhancements may, in virtue of changing normal species functioning, also change what counts as a nanotechnology-based human enhancement.

¹² One might object to considering any arguments for or against nanotechnology-based human enhancement that alters the human species given that such enhancement may never bring such radical changes to humankind. But scientists are already doing research that may lead to such enhancement. And it is better to consider the ethical consequences of possibilities that may never materialize than to be unprepared for those that do [10, 82].

An Aesthetic Argument Against Nanotechnology-Based Human Enhancements

One way of arguing that nanotechnology-based human enhancements that alter our species should be prohibited is this:

- 1) Our species, like many other naturally occurring species, has aesthetic value.
- 2) If our species, like many other naturally occurring species, has aesthetic value, nanotechnology-based human enhancements that alter our species should be prohibited.
- 3) So, these enhancements should be prohibited.

There are many reasons to care about naturally occurring species. One class of reasons is aesthetic [16, 69]. There are different ways of thinking about aesthetic value. Many believe aesthetic value is objective [8, 12, 14, 47]. If aesthetic value is not objective, then altering our species might change this value in odd ways. For instance, some psychological nanotechnology-based human enhancements might accidentally change our perception of ourselves and hence, on subjective accounts of aesthetic value, our species' aesthetic value. Although this may not cause problems for the argument below,¹³ let us suppose here that aesthetic value is objective. Let us suppose that if species have aesthetic value, they possess value independently of at least humans' opinions on the matter [61, 165].

To show that our species has aesthetic value and nanotechnology-based human enhancements that alter our species undermine this value, we must say a few words about species. There are different ways of understanding whatever definition of *species* turns out to be correct. On one way of thinking about species, a species is just all of the particular individuals of a type. So if there were ten red deer left in the world, the species *cervus elaphus* would just be those ten animals. Alternately, a species may be a type or category.¹⁴ On this way of understanding species, *cervus elaphus* is better understood as something like

¹³ On this see [85].

¹⁴ For more detail on different ways of classifying species see [25].

a natural kind.¹⁵ We will consider arguments for preserving our species understood in both of these ways.¹⁶

Perhaps species, thought of as a collection of individuals, are aesthetically valuable, in part, because their constituents are aesthetically valuable [68]. To make this case, one must first show that individual members of a species can have aesthetic value. Often arguments for the aesthetic value of individuals are made by analogy. Eagles and leopards are supposed to be like art works in evoking in people aesthetic experiences [35]. Individual members of some species need not be pleasant or beautiful to have aesthetic value. But their colors, shapes, sounds, and textures can be as striking as the colors, shapes, sounds and textures of art objects. Of course, some individuals may lack aesthetic value and some may have more aesthetic value than others. Most razorback suckers and caddis flies, for instance, may have less aesthetic value than most leopards or egrets [68]. Still some species' members can invoke feelings as sublime as the feelings art evokes [61, 174]. Supposing, then, that it is clear how one might argue that an individual member of a species has aesthetic value, one might argue that a species has aesthetic value in part because its members have aesthetic value. A species may be like a forest whose beauty results largely from the beauty of its trees, grass, and so forth.

Now, a collection of individuals may have less aesthetic value than its parts. For instance, each individual plant in a garden may be aesthetically pleasing, while the collection might, together, have little aesthetic value. But a collection of individuals may also have as much or more aesthetic value than its parts. Old growth forests, after all, often have more aesthetic value than the individual plants that make them up. One might argue that the aesthetic value of many species is more like the aesthetic value of an old growth forest, with that kind of organic unity and harmony, than a poorly constructed garden. On this account, the aesthetic value of the redwood species,

for instance, far exceeds the aesthetic value of most individual redwood trees. One might suggest that this is because the ways that the members of such species work and live together with other parts of nature are aesthetically valuable [61, 174]. The redwood, as a species, is a community of trees living in community with many other species. The redwood plays many ecological roles as a species that give it aesthetic value beyond the aesthetic value of its parts. In fact, some of those who talk about the aesthetic value of species seem to think species gain aesthetic value in exactly this way [46].

Suppose, instead, one adopts a conception of species as a category or type. Then, one might not think species have the kind of aesthetic value gardens or forests possess. On the categorical understanding of species, members of a species do not work together like the parts of a forest or garden. They are simply members of a class. So, one might follow Allen Carlson in arguing that species as categories or types have aesthetic value for a different reason. They have (or suggest or stand for something which has) the aesthetic value exemplified by their paradigmatic members [15]. On this account, the species *cervus elaphus*, for instance, has (suggests, or stands in for something which has) the aesthetic value exemplified by the paradigmatic or normal *cervus elaphus*.

Perhaps one of these arguments can show that our species has aesthetic value. If one thinks of a species as a collection of individuals, one might argue as follows. Our species has aesthetic value because individual humans and the ways that individual humans live and work together with their larger environments have aesthetic value. There is, thus, reason to preserve the human species. If, on the other hand, one thinks of a species as a category or type, one might argue as follows. Our species has aesthetic value because it has (stands in for or suggests something which has) the kind of aesthetic value exemplified by the paradigmatic human. So there is reason to preserve our species.

Both kinds of argument may have problems, however. Consider one possible problem for arguing that we should preserve our species because our species as a collection of individuals has aesthetic value: we could easily lose this kind of aesthetic value. Suppose all of the members of our species lost their aesthetic value. Suppose, too, that the ways in which members of our species live together with other

¹⁵ Although this may be a bit misleading as types and categories can be understood in many ways, the basic idea should be clear. Types or categories may, for instance, be understood as Platonic entities or Aristotelian essences, as kinds, sets, classes, universals or whatnot [83]. Those who are interested, may see [83] for different ways of understanding types and categories and relevant references.

¹⁶ For other ways of thinking about the aesthetic value of nature see [7, 11, 13, 26, 36, 66, 71, 76].

species and our larger environment lost such value. Then, our species would no longer be aesthetically valuable. Suppose, for instance, a plague disfigured everyone and left us interacting with other species and our larger environment only in blighted ways. Our species might lack aesthetic value. In this kind of case, the only aesthetic reasons we might have to preserve our species would have to look to the future or the past. If we had reason to believe our species would recover and gain aesthetic value in time, there might be reason to preserve our species. Alternately, our past aesthetic value might give us reason to preserve our species.

There may also be problems for the argument that our species as a type has aesthetic value. Our species construed as a type may continue to exist without instantiations.¹⁷ If so, then it is not clear that we could do anything to eliminate our species. So, one might have to argue that we should preserve individual members of our species because it is only possible to access our species' aesthetic value via its instantiations.¹⁸

One general objection to the idea that a species, on any conception, has aesthetic value of a sort that could justify preservation is this. Aesthetic value is purely instrumental so, if species have aesthetic value, they have a kind of instrumental value; individuals or types can have aesthetic value only because they give rise to aesthetic experiences. "Unlike mountains, however, which do have some instrumental value, species have none at all... a species does not really do anything for its member exemplifications, the environment, or human beings" [35, 173]. So, species do not have aesthetic value.

The objection here may be something like this:

- 1) Aesthetic value is purely instrumental value.
- 2) Species do not have instrumental value.
- 3) So, species do not have aesthetic value.

The first premise of this argument is not clearly correct, however. Aesthetic value need not be merely instrumental. Though, part of an aesthetic object's value may be in its giving rise to aesthetic experiences. Suppose we have a cave painting that only has

aesthetic value. Suppose, further, that we know that the painting will be damaged if it is exposed to light. There are two things we can do. We can keep viewing the painting, allowing it to deteriorate. Or, we can close the cave forever and preserve the painting. If we close the cave, we think the painting has some non-instrumental aesthetic value [35, 172]. Similarly, we might think that a species has non-instrumental aesthetic value. If so, we might in similar situations refuse to use the species to garner aesthetic experience. If, for instance, the red deer's existence was threatened by human encroachment on its territory, we might not let people approach the deer even just to take pictures.

The second premise of the above argument, that species do not have instrumental value, is also implausible. If species have aesthetic value and part of this value is instrumental, species have instrumental value. Species may also have instrumental value for other reasons. Species may play important roles in ecosystems or contribute to biodiversity [9].

On this way of understanding the nature of aesthetic value one might argue by analogy that nanotechnology-based human enhancement is impermissible. The aesthetic value of humanity might explain why it is impermissible to use nanotechnology-based human enhancement that eliminates our species, just like the aesthetic value of the last redwood grove might explain why it is impermissible for the last man on earth to cut down the last grove (Routley 1973 cited in [85]). Similarly, our aesthetic value might make it impermissible to use nanotechnology to alter our species, just like the last man could not use spray paint to alter the last redwood grove.

It is not clear that this argument goes through. Not all enhancement is unacceptable. We would almost certainly have encouraged van Gogh to enhance *Starry Night* by putting the finishing touches on the picture, had he considered stopping prematurely. And, even enhancement that creates something entirely new may be acceptable. It may be okay to use nanotechnology-based human enhancements to create new species in addition to our own. Could not such species have aesthetic value as well? Newly created species may even have more aesthetic value than unenhanced species, just like newly created art works may have more aesthetic value than old artworks. So perhaps we should create other species too. And if a new species could have more aesthetic value than our

¹⁷ See [83].

¹⁸ Alternately, one might try to deny the premise and argue that types can only continue to exist with their instantiations. On how this might be possible see [83].

species it might even be acceptable to replace our species with another.

One way of objecting to this line of thought is to argue that species have aesthetic value because they are natural (as opposed to artificial) entities. This might explain why some people do not value mules and other created species as much as naturally occurring species [31].¹⁹ Though created species might become more valuable over time as they evolve into something more wild, newly created species might lack an important kind of value. If phenomenologically and functionally identical plastic redwoods took the place of natural redwoods, an important kind of aesthetic value would be lost [68].

One might reply here that the ground of species' aesthetic value does not rely on a species' being natural (i.e., not artificial). Even if currently existing species are aesthetically valuable partly because they are natural, newly created species might have a different kind of aesthetic value. After all, many artificial artworks (i.e., those that result from intentional human control) are valuable. Even if newly created species do not have more value than our species, it is hard to see how one might object to creating a new species with a different kind of aesthetic value in addition to ours. It might be fine to create a species of enhanced humans in addition to unenhanced humans just like it is okay to create plastic redwoods in addition to real redwoods.

The defender of the aesthetic argument against nanotechnology-based human enhancement might respond with an analogy. Just as we would not have let Picasso paint over a van Gogh (even if Picasso were better than van Gogh), we should not create another, similar, species by enhancing our species with nanotechnology. Such enhancement, in virtue of being enhancement rather than simply creation would be like painting over the human canvas. There may be no good objection to creating a new (e.g., robotic) species from scratch but, one might conclude, nanotechnology-based human enhancement is not acceptable.

¹⁹ There are, of course, some people who think created species usually have more value than naturally occurring species. Many people, for instance, seem to find corn aesthetically pleasing although the development of common varieties took a great deal of intentional human modification; note, for instance, the great number of festivals celebrating corn. We can grant the objector's claim for now, however.

Unfortunately, it is not clear that this is a good analogy. Perhaps nanotechnology-based human enhancement does not require using the human canvas in a problematic way. If we let Picasso paint over a van Gogh we would lose the van Gogh. We do not necessarily lose the human species by allowing some human enhancement. Furthermore, some enhancements (e.g., enhancements that improve individuals' immune systems) may be more like touching up a painting to preserve it than like painting over one. Just as touch-ups are often acceptable, some enhancement may be acceptable.²⁰ Finally, even if we did completely alter human nature with enhancement, that might be okay. Our (historical) species may not be as aesthetically valuable as the species we might create. Newly created species may have more aesthetic value than our unenhanced species even if new species' value is of a different type. We might let Picasso paint over *Starry Night* if he could create something better. We would probably let him paint over art that was significantly worse than what he could create.

To be honest, I do not know exactly how one might reply to this line of thought. It seems that there are significant problems with arguing against altering our species because of its aesthetic value, especially if we do not destroy our species in the process. As stated, the aesthetic argument against nanotechnology-based human enhancements that alter our species is probably too ambitious. If, however, our species has great aesthetic value, we may have at least a *prima facie* reason to preserve our species. Furthermore, aesthetic considerations might come into play in other kinds of arguments against nanotechnology-based human enhancements that alter our species. It might be impermissible to alter our species because we contribute to biodiversity or play (aesthetically?) valuable roles in different ecosystems. After all, some suggest that "biodiversity is a precious global resource..." and go on to argue that "...the disappearance of snail darters, gorgeous tropical birds, and African beetles impoverishes the earth" [3, p. 75]. One might make a similar case against altering the human species. So, let us consider one potential argument along these lines now.

²⁰ This is especially likely if species membership is not an all or none affair.

An Argument from the Value of Our Species' Role in Ecosystems

Consider the following argument:

- 1) Our species plays valuable ecological roles.
- 2) Nanotechnology-based human enhancements that alter our species are likely to interfere with our species playing our ecologically valuable roles.
- 3) If nanotechnology-based human enhancements that alter our species are likely to interfere with our species playing our ecologically valuable roles, such enhancements are impermissible.
- 4) Nanotechnology-based human enhancements that alter our species are impermissible.

To explicate this argument, we must explain what it means for a species to play a valuable role in an ecosystem. We can then try to show that our species plays valuable ecological roles. Finally, we can try to make the case that nano-enhancement that alters the human species is likely to interfere with our playing these roles.

Very roughly, ecosystems are made up of organisms occupying a physical area along with their abiotic physical environment linked by nutrient cycling and energy flow. Nutrient cycling occurs when elements like oxygen and nitrogen are exchanged between the biotic and abiotic members of an ecosystem. Energy flow is just the flow of energy from sunlight through a food chain.

Although ecosystems may not be sharply defined, they can often be distinguished by their constituent functions as well as member organisms or abiotic environments. Wetlands, for instance, are often distinguished in terms of their functions—improving water quality for fish and people, water storage and so forth. Redwood forest ecosystems, on the other hand, are often picked out by their largest members—redwood trees.

A species' role in an ecosystem, then, is composed of the (nutrient cycling and energy flow) links between that species and other elements of the system. So part of the redwoods' ecological role is to provide nutrients to algae and insects. Algae and insects provide energy for birds in both forest and wetland ecosystems.

As with species, there are different ways of thinking about ecosystems and ecological roles. For instance, a species' role may be 1) the *kinds* of causal

interactions occurring between members of that species and the other parts of the ecosystem or 2) reducible to the particular causal interactions occurring between members of that species and the other parts of the ecosystem. The arguments that follow, however, will not hinge on one way of construing ecosystems or ecological roles as opposed to another.

To see why one might think species can play valuable ecological roles consider an excerpt from Rachel Carson's [17] brilliantly written *Silent Spring*. In *Silent Spring* Carson describes the ecological roles the sage, grouse, and antelope have historically played in Western prairie ecosystems.

The sage and the grouse seem made for each other. The original range of the bird coincided with the range of the sage, and as the sagelands have been reduced, so the populations of grouse have dwindled. The sage is all things to these birds of the plains. The low sage of the foothill ranges shelters their nests and their young; the denser growths are loafing and roosting areas; at all times the sage provides the staple food of the grouse. Yet is a two-way relationship. The spectacular courtship displays of the cocks help loosen the soil beneath and around the sage, aiding invasion by grasses which grow in the shelter of sagebrush. The antelope, too, have adjusted their lives to the sage. They are primarily animals of the plains, and in winter when the first snows come those that have summered in the mountains move down to the lower elevations. There the sage provides the food that tides them over the winter. Where all other plants have shed their leaves, the sage remains evergreen, the gray-green leaves—bitter, aromatic, rich in proteins, fats and needed minerals—clinging to the stems of the dense and shrubby plants. Though the snows pile up, the tops of the sage remain exposed, or can be reached by the sharp, pawing hoofs of the antelope. The grouse feed on them too, finding them on bare and windswept ledges or following the antelope to feed where they have scratched away the snow [17, p. 65, 66].

It is plausible, given this description, to conclude that there is something (perhaps aesthetically!) valuable about the roles the sage, grouse, and antelope play on the Western prairies.

One might not find this example compelling, however. One might not think this example can show that species like the sage, grouse, or antelope play *morally* or *aesthetically* valuable ecological roles, though each species' playing its role may help maintain the ecosystem. If another species played the role of the sage, for instance, perhaps that would be just as well.

I do not believe that this is correct. I believe that there is a kind of aesthetic value in these creatures playing the roles that they do in the ways that they do. But this point is not essential. Even if other creatures could play these roles as well, one need only agree that there is some (even if contingent and instrumental) value in some species playing the roles they do.

There are many reasons why it might be contingently and instrumentally valuable for species to play their ecological roles. It may, for instance, be valuable for species to play their ecological roles for purely anthropocentric (human-based) reasons [85]. Of course, one cannot non-circularly suggest that we should preserve our species because it must play certain ecological roles to be preserved. Some arguments for preserving our species that are ultimately grounded in the survival, interests, identity or whatnot of individual humans might be acceptable, however. The survival, identity, or enjoyment of individual humans may depend on species playing the roles that they do. This may explain the value of these roles. We may enjoy looking at antelope and eating grouse, we may identify as people from the sage-brush filled American West [39].

Alternately, it may be valuable for species to play their ecological roles for non-anthropocentric reasons. These roles might, for instance, support non-human species or individuals [17]. Were the grouse's ecosystem without sage, the grouse might not survive. The value of the sage playing its ecological roles might itself derive in part from the value of the grouse (or the antelope). Finally, it may be valuable for a species to play a given ecological role because this role sustains the beauty or integrity of the ecosystem or biosphere of which the species is a part [46]. Even species that do not survive within a given ecosystem may benefit that ecosystem by putting adaptive pressure on those species that do survive. Those that do survive may make a valuable contribution to biodiversity [58].

There are, however, many ways of arguing that some ecological roles lack value too. Suppose one

takes a purely anthropocentric perspective. From this perspective, some ecological roles may not be valuable. Some roles, like that of the malaria-carrying mosquito, may threaten human interests, identities, and survival [86]. There are also non-anthropocentric reasons for thinking some ecological roles lack value. Some ecological roles may threaten non-human individuals, species, and ecosystems [68]. Beavers on the plains have a habit of turning the plains into wetlands threatening many individuals in the process.²¹ When their population density is high, as it is in South Africa's Kruger National Park, elephants turn forests into plains threatening endangered species like rhino and baobab trees [84]. Even from a biocentric perspective—focusing only on the value of a species to the biosphere—some ecological roles may lack value. If elephants do eliminate rhino or baobab trees, biodiversity may decline, and the biosphere may suffer accordingly.

Given that some ecological roles may not be valuable, why think that humans play valuable ecological roles? This question is a good one. But, as long as one grants that some ecological roles are valuable, it is quite possible that our species plays such roles. To show that our species plays valuable roles, one might argue that some of the ecological roles our species plays benefit individuals, other species, ecosystems, or the biosphere. Suppose, for instance, that one thinks it is valuable for a species to play an ecological role if that species playing that role helps another species survive. Many species, like Micronesian Kingfishers, exist only in captivity. They depend on humans for their food and so forth [23]. Insofar as one of our ecological roles is to provide this sustenance for these species there would be value in our playing this role.

One might object, however, that our species' roles sometimes harm individuals, other species, and even ecosystems [17]. After all, the Micronesian Kingfisher is endangered because a brown tree snake snuck onto a plane in World War II [23]. Without humans, the Micronesian Kingfisher probably would not have

²¹ Of course, all organisms that eat other organisms harm some individuals and even organisms that do not eat other organisms often harm some individuals by altering their environments. Some species, however, are more destructive than others given their historical circumstances, and beavers are probably among the most destructive species around today.

needed our assistance at all. Or, consider our role on the sagebrush plains of the American West.

The bitter upland plains, the purple wastes of sage, the wild, swift antelope, and the grouse are then a natural system in perfect balance. Are? The verb must be changed—at least in those already vast and growing areas where man is attempting to improve on nature's way. In the name of progress the land management agencies have set about to satisfy the insatiable demands of the cattlemen for more grazing land. By this they mean grassland—grass without sage. So in a land which nature found suited to grass growing mixed with and under the shelter of sage, it is now proposed to eliminate the sage and create an unbroken grassland. Few seem to have asked whether grasslands are a stable and desirable goal in this region. Certainly nature's own answer was otherwise. The annual precipitation in this land where the rains seldom fall is not enough to support good sod-forming grass; it favors rather the perennial bunch-grass that grows in the shelter of the sage... The eventual effects of eliminating sage and seeding with grass are largely conjectural. Men of long experience with the ways of the land say that in this country there is better growth of grass between and under the sage than can possibly be had in pure stands, once the moisture-holding sage is gone. But even if the program succeeds in its immediate objective, it is clear that the whole closely knit fabric of life has been ripped apart. The antelope and the grouse will disappear along with the sage. The deer will suffer, too, and the land will be poorer for the destruction of the wild things that belong to it [17, p. 66–67].

Our species may harm individuals, other species, and ecosystems.

This all seems fair enough. But since our species may not only harm but may also help some individuals, species, and ecosystems, what we really need to know is whether it is generally a good thing for humans to play their ecological roles. The ecological argument against nanotechnology-based human enhancement can neither be made nor proven wrong by pointing to some of the valuable or harmful roles our species plays.

Perhaps the opponent of the ecological role argument against nanotechnology-based human enhance-

ment can argue that it is not generally a good thing for humans to play their ecological roles. The opponent of the ecological role argument might suggest that, throughout history, humans' arrival in different ecosystems has been incredibly destructive [21]. The arrival of humans in North and South America may have led to widespread extinction of American megafauna. The Maoris probably killed off the last Moas in New Zealand. Human forest fires may have caused the extinction of native plants on Easter Island. Our domesticated animals may have caused widespread desertification in the Middle East [22, 28]. There is also reason to believe many species will go extinct in the future because of anthropogenic environmental destruction [77]. Climate change, for instance, could be catastrophic [42]. If the Antarctic Ice Sheet collapses, sea levels may rise 4–6 meters [30]. Climate change could disrupt important temperature moderating ocean currents [30]. Worst case scenarios include massive droughts, extensive flooding, or even another ice age [54]. Many species may perish [87]. Our species may play a rather destructive ecological role in most ecosystems [75]. Perhaps it would be better if nanotechnology-based human enhancement changed our destructive nature or simply eliminated our species.

It is not clear that this objection goes through. There are deep empirical and philosophical issues here. The objection seems to be this:

- 1) Our species has caused and will cause massive extinctions.
- 2) If our species has caused and will cause massive extinctions then it is not generally a good thing for humans to play their ecological roles.
- 3) So it is not generally a good thing for humans to play their ecological roles.

Consider some empirical issues that may undermine the objector's case for this argument's first premise. It is not clear that our species was responsible for massive historical extinctions. Epidemics or non-anthropogenic climate change may have been responsible [60]. Nor is it clear that anthropogenic environmental destruction will cause massive extinction in the future. We might stop destroying the environment and help preserve species instead.

Next, consider some philosophical reasons to question this objection's second premise. Let us grant for a moment that we have caused and will cause

many species to go extinct. We cannot conclude from this fact alone that the ecological roles our species plays are bad in general. Although we may harm many species, we may benefit individuals, other species, ecosystems, or the biosphere in the process. When beaver turn plains into wetlands they create problems for species that prefer plains, but other species including fish and waterfowl benefit [62]. When elephants turn forests into plains, rhino and baobab trees suffer but other species flourish [84]. Similarly, we can be pretty sure that we will have some positive and some negative effects on some present and/or future individuals, other species, ecosystems, and the biosphere. Even if anthropogenic climate change does bring about another ice age, some individual penguins and polar bears may benefit, though many tropical birds will suffer. Arctic ecosystems may flourish and deserts may disappear.

All things considered, it may even generally be a good thing for humans to play their ecological roles, though they also destroy many other individuals or species, alter ecosystems, and transform the biosphere. Consider elephants and beaver again. Some environmentalists argue that elephants play a valuable role in Kruger National Park when they open the vast savannah by tearing down forests, even if this threatens the survival of species like rhino and baobab [39, 84].²² Most environmentalists want to protect beaver because they help create wetlands by flooding plains [78]. Even if beavers and elephants caused some species to go extinct by transforming their ecosystems, environmentalists might maintain that their destruction is creative; that it is generally a good thing for these species to play their ecological roles [58]. Humans, like elephants and beavers, might bring creative destruction. They might exert adaptive pressure on other species. Humans might open up new evolutionary niches, make ecosystems more dynamically and resiliently stable, or enrich the earth by creating new ecosystems [59].

Consider how one scientist put the point in response to those who worry about extinction in particular:

To the conservation biologist, there is little positive to be said about extinction. From an

evolutionary perspective, however, extinction is a double-edged sword. By definition, extinction terminates lineages and thus removes unique genetic variation and adaptations. But over geological time scales, it can reshape the evolutionary landscape in more creative ways, via the differential survivorship of lineages and the evolutionary opportunities afforded by the demise of dominant groups and the postextinction sorting of survivors [41].

If we take a long enough perspective, it may even turn out that it is generally a good thing for humans to play their ecological roles, even though we are destructive in some respects. We may be like early cyanobacteria. These early photosynthesizers probably reproduced so prolifically that they greatly depleted the atmosphere of the carbon dioxide that all existing individuals and species needed to survive. But, in the process, they produced the oxygen that allowed aerobic organisms to evolve [19].

To argue that our species plays generally valuable or destructive ecological roles, we would need to decide how much each of our species' effects matters [67, 72, 73].²³ Would it be bad if we caused massive extinctions but benefited the biosphere in the process? Would it be good if our species helped other species but at significant cost to many individuals? Environmentalists are bitterly divided over such questions [74, 80]. But even if one could convincingly argue for a metric that would allow us to compare different ways our species might affect individuals, other species, ecosystems, and the biosphere, difficult empirical questions would probably reappear. It is at least as hard to determine how our species has or will affect individuals, ecosystems, and the biosphere as it is to determine how our species has or will affect other species. So it would probably be hard to show that our species' net effect on individuals, other species, ecosystems, and the biosphere is or will be good or bad [9].

²² Kruger is about the size of Israel and contains several ecosystems.

²³ If we did not play a destructive role in some ecosystems other species might play even more destructive roles. Humans nearly eliminated beaver populations on the plains that might otherwise have destroyed trees and plants flooding sage land and creating wetland ecosystems [55]. If their destruction would have been greater than ours, would it have been a good thing that we caused this destruction?

It seems that, right now, we simply do not know whether it is generally a good thing for humans to play their ecological roles.²⁴ So what should we say in the absence of this knowledge? To figure out what we should say, it might help to consider what environmentalists do say about beaver, elephants, and other species that essentially change the ecology of their environments. Should we allow weeds like crabgrass or kudzu to take over environments in which they appear or try to alter or destroy them? Do their roles have value independent of their effects? Different environmentalists respond differently [45, 48]. Some want to control species like elephant and beaver by modifying their natural behavior or culling. While, as we have seen, other environmentalists say we should not interfere with species playing their ecological roles. These environmentalists believe that we should even let be those species that, given their historical circumstances, seem to have the most destructive effects on their environments [53, 84].

Those who believe we should not interfere with other species argue that it is valuable for species to play their wild, uncontrolled roles in their ecosystems.²⁵ Some rest their case on the proposition that the destruction such species bring is creative. But, others argue that the roles species play are valuable independent of their effects [53, 58].²⁶ These environmentalists sometimes suggest that species' roles are valuable precisely because they are wild, free from intentional attempts at human control [53].

²⁴ Consider, for instance, how 'the interplay between the destructive and generative aspects of extinction, and the very different time scales over which they appear to operate, remains a crucial but poorly understood component of the evolutionary process' [41].

²⁵ This may be because such roles are natural. See [53, 70].

²⁶ One worry about trying to restore natural environments by controlling invasive species is that it is not clear to which state we should restore any given environment. Ecosystems are in continuous flux. They do not have stable states. Some argue, for instance, that we would need to restore western plains not merely by stopping any future sage brush eradication but by replanting the sage we have destroyed, reintroducing the wolves we eradicated before the sage, or even reintroducing (genetically similar proxies for) the Pleistocene-era mega-fauna like lions and elephants the first Americans from Eurasia may have helped eliminate 13,000 years ago [22]. But perhaps these debates can be resolved.

Unfortunately, we probably cannot use this last line of thought to show that there is value in letting humans radically reconfigure their environments. We do not play many wild roles in the relevant sense; our roles are not free from intentional attempts at human control. Humans do almost everything intentionally. Most of our ecological roles are shaped by our conscious actions.

It seems that we have reached an impasse. Though humans certainly play some valuable ecologically roles, it may not generally be a good thing for us to play our ecological roles. Further philosophical argument (and perhaps data about how our ecological roles affect individuals, other species, ecosystems, and/or the biosphere) is necessary to show that many of our ecological roles are valuable. In the absence of this argument (and the requisite data), it is not clear that there is reason to preserve our species so that we can continue to play our roles.

Furthermore, for the ecological role argument to go through as stated, we would have to show that nano-enhancement that alters the human species would interfere with our generally playing valuable ecological roles.²⁷ Consider how nanotechnology-based human enhancement might interfere with humans playing an important ecological role. Suppose nanotechnology-based human enhancement made it impossible for people to contract a parasite or virus that must spend part of its lifecycle in human hosts (like malaria). If that virus or parasite did not threaten the human species but was essential for controlling wild animal populations, enhancement that eliminated our role as temporary host could have devastating results for some ecosystems. It is implausible, however, to think that nano-enhancement that alters the human species would interfere with our generally playing valuable roles. There are many ways that nanotechnology-based human enhancement might alter our species without interfering with our (generally) playing valuable roles. Our species might change if, for instance, enough people started using nanotechnology-

²⁷ Presumably nanotechnology-based human enhancement would interfere with our species playing a valuable ecological role if such enhancement prevented our species from playing that role or undermined the value of that role by altering it in some way. Obviously, many things besides nanotechnology-based human enhancement could and probably do interfere with our species playing valuable ecological roles.

based artificial muscles. That probably would not interfere with our (generally) playing valuable ecological roles.

Perhaps one could defend a slightly amended version of the argument. One might suggest that since nano-enhancement *could* interfere with our generally playing valuable roles, we should prohibit such enhancement. One might appeal to a precautionary principle to justify the prohibition. This precautionary principle might require certain, reliable evidence that the effects of new technologies on individuals, other species, ecosystems, and the biosphere are acceptable before allowing their development or use [51].

This suggestion is too sweeping. It would prohibit the development and use of all new technologies including new vaccinations and medicines.²⁸ After all, any new technology *could* interfere with our generally playing valuable ecological roles. We do not have certain and reliable evidence that rules this out with certainty for any new technology. But small risks do not give us a reason to stop developing and using new technology.²⁹

Besides, there are other problems for arguing that nano-enhancement that alters the human species would interfere with our generally playing valuable ecological roles. If nanotechnology-based human enhancement just created an additional species, our (historical) species might go on playing its usual roles. Alternately, even if nanotechnology-based human enhancement changed the nature of our species entirely, such enhancement might create a new species that could take over our valuable roles or play yet more valuable roles.³⁰ One might try to respond to this last problem by suggesting that there is a kind of irreplaceable aesthetic value in natural species playing their ecological roles. But we have already explored and found that line of reasoning to be wanting. Enhanced creatures playing similar ecological roles could have even greater, though different, aesthetic value. So, even if

it is generally a good thing for humans to play their ecological roles, even nanotechnology-based human enhancement that eliminated our species might be acceptable.

In short, the ecological role argument against nanotechnology-based human enhancement has similar problems as the aesthetic argument against such enhancement. Nanotechnology-based human enhancement may not prohibit our species from playing its valuable ecological roles. Whatever reasons we have to value our unenhanced species' roles may not be able to trump whatever reasons we might have to value enhanced species' roles. Enhanced species' roles may even be more valuable than our unenhanced species' roles.

Conclusion

Few have considered reasons why we should preserve the human species, in particular, or whether traditional arguments for preserving species might give us reason to preserve our species. This paper has begun this inquiry. It critically examined whether two of the strongest arguments for preserving other species could be applied against nanotechnology-based human enhancements that alter human nature. First, our species, like many other naturally occurring species, has aesthetic value. So, nanotechnology-based human enhancements that alter our species should be prohibited. Second, our species plays valuable ecological roles. Nanotechnology-based human enhancements that alter our species are likely to interfere with our species playing our ecologically valuable roles. So, such enhancements should be prohibited.

There may be aesthetic value in our species. Our species may also play valuable ecological roles. But, even if one defended these conclusions fully, nanotechnology-based human enhancement may sometimes be permissible. Only some kinds of nanotechnology-based human enhancement will undermine our species' aesthetic value or the roles it plays (e.g., those that eliminate our species without coming up with a suitable replacement). Furthermore, even when a nanotechnology-based human enhancement would undermine our species' aesthetic value or the roles it plays, one would need to show that the losses would not be outweighed by gains from such enhancement. Nanotechnology-based human enhance-

²⁸ For more detailed exposition and criticism of different versions of the precautionary principle see [51].

²⁹ Better precautionary principles might be justified by analogies between new technologies that pose unknown risks and technologies that have posed large risks in the past [38]. Nevertheless, I do not see how one might argue by analogy that nano-enhancement poses a large risk of undermining our generally valuable ecological roles.

³⁰ There may also be reasons to worry that new species could play destructive roles.

ment might create other species that have aesthetic value or play important roles in their (or our) ecosystems. Unless stronger arguments for preserving species can be found in the environmental ethics literature, the prospects for showing that nanotechnology-based human enhancements are impermissible using such arguments are dim.

Still, we have learned something from this paper's inquiry. Although neither of the arguments we considered seem likely to go through as stated, they failed in noteworthy ways. In light of the environmental destruction our species causes, one might have thought it obvious, for instance, that our species does not play many valuable ecological roles. The paper argued, however, that this is not so clear. Philosophical argument (and perhaps additional evidence) is necessary to show that humans' ecological roles are not generally valuable. Furthermore, each of the arguments we have considered may contain a grain of truth. Even if nanotechnology-based human enhancement is permissible, there may be something morally problematic about some such enhancements. If one can make the case that our species has aesthetic value or plays valuable roles, there is *prima facie* reason not to pursue nanotechnology-based human enhancements that interfere with this value or these roles. The considerations underlying both arguments may give us reason not to do enhancements that undermine our species' aesthetic value or the valuable roles we play. And, more generally, considerations underlying other arguments for preserving species in the environmental ethics literature may advance debate about nanotechnology-based human enhancements. Such arguments merit further exploration.

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