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THINK GALACTICALLY, ACT MICROSCOPICALLY?

The Science of Scale in Video Games

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> I meant no harm. I most truly did not.
> But I had to grow bigger. So bigger I got.
>
> —The Once-ler, in Dr. Seuss's *The Lorax*

> The greatest shortcoming of the human race is our inability to understand the exponential function.
>
> —Dr. Albert A. Bartlett[1]

Fixtures of the domestic interior, computer, and video game systems can seem woefully remote from the proliferating concerns of the outer world. But while early Christian doctrine and Greek natural philosophy alike designated the world as a Book of Nature, today the physical world is intensely mediated and remediated not just by textual forms, but by photos, movies, soundtracks, apps, tchotchke, and even digital games. In this vastly expanded media universe, the Book of Nature warrants reimagining—but as what? As our material and virtual lives continue to converge, perhaps nature too has become the stuff of pixels and polygons.

To date, the dual categorization of games as technology and as recreation has shielded them from vital questions about how they model natural environments. While growing numbers of academics and game designers have worked to establish games' artistic, educational, and social value, few have yet asked pointed questions about how games exhibit and influence human environmental understanding. For a moment, let us entertain the provocation that the video game is the book's appropriate successor as metaphor for the world. To speak of the Game of Nature, facetiously or no, would be to acknowledge not only the growing influence of virtual realities on our everyday lives, but also the modern tendency to treat nature as the stage for everything from leisure to business to near-constant anxiety about future outcomes. Gamers and nongamers alike have been deeply impacted by computer-driven practices that arguably achieve their clearest manifestation in games, among them graphic immersion, telecommunication, social networking, and the exchange of virtual currency. What's more, those of us who enact our daily routines deeply conscious of a desire to avert the worst of climate change predictions travel through a time and space that are undeniably game-like, in that they are profoundly shaped by cause and effect and sometimes stultifying calculations of risk and reward. What a ludic world metaphor makes visible is this growing overlap between real and virtual worlds, whether through painstakingly rendered three-dimensional digital environments or our propensity to map conventions derived from one to the other, and vice versa.

Here at the nexus between media and ecology, questions of dimension invariably arise. Environmental thinking calls for suprapersonal awareness of the impact and extent of one's actions: What's the big deal if I rely on bottled water rather than tap water? How many thousands of kilometers of fiber-optic cable must be laid to satisfy our desire for broadband connectivity? How much is too much, and when is enough enough? Environmental representation confronts an additional edifice of ideals around realism and transparency: does verisimilitude demand one-to-one mapping, or does simplification allow patterns to emerge more readily? In my mind, games are tailor-made to develop scalar environmental consciousness, for instance by operationalizing relations between the local and the global. As the following brief review of the scientific literature on scale in ecological journals will suggest, video games share certain fundamental qualities with field and laboratory experiments, and both players and scientists exercise their creative and rational faculties to make sense of the worlds around them.

First, several caveats are in order. Like sustainability, the watchword of this volume, scale means many things to many people. Groups as diverse as mapmakers, human geographers, field ecologists, and computer scientists use the term but seldom agree on its definition, in part because scale is inherently relational. As Willard McCarty has said of models, scale implies at minimum a ternary structure between measure-taker, that which is being measured, and the measure itself.[2] In practice, this has meant that scale serves equally well as an instrument of revelation and distortion. Scalar arguments have accordingly been both the clarion call and the bête noire of environmental movements—picture the Leonardo DiCaprio–narrated *The 11th Hour* (dir. Leila Connors-Peterson and Nadia Connors, 2007) and the bumper-sticker mantra "think globally, act locally" alongside Malthusian declamations of population growth and the gleeful globalization rhetoric encapsulated by Dr. Seuss's Once-ler and his "figgering on biggering."[3] For my purposes, scale is less significant as a graded system of measurement than as an acknowledgement of interspecies and Latourian interobjective relativity. That is to say, scale connotes dependence as well as magnitude. The word may conjure the undue tidiness of architectural miniatures and the conformation of environments to users, but it also makes possible a thinking through of excess, a thinking *beyond* in the realm of hyperobjects.[4]

In what follows, I hope to reveal some of ecology's potential affinities with digital interactive media.[5] At the same time, this chapter is also intended as an initial inquiry into the variations in scalar representation across media. While I want to resist characterizing the transition from print and photography to the moving image (*Powers of Ten*) to the sandbox simulation game (*Spore*) as progressive teleology, I will argue that contemporary games offer quantitatively and qualitatively distinctive opportunities for the representation of pressing ecological quandaries. Where Ralph Waldo Emerson once described poetry as possessing a rare ability to "magnify the small" and "micrify the great," thereby transforming our perception of the material world, I present games as both an aesthetic and an ethical means to engage in world design and management, one especially well suited to exploring questions of sustainable action and scope.[6] Understanding how scale is defined and instantiated in our media culture should be of paramount importance in an age vexed by parochialism, transnational corporate ambitions, and borderless phenomena of minute and massive proportions, from toxic contamination of living tissue to ocean eddies and extreme weather.

Leveling Up (and Down) in the Lab and in the Living Room

> Graphical excellence is nearly always multivariate.
>
> —Edward R. Tufte[7]

Experts across the disciplinary spectrum express mixed feelings about scalar models, seeing them as necessary and illuminating frameworks on the one hand, and falsely subordinating constructs on the other.[8] We might expect scientists to have fewer qualms, but lately many have been at pains to historicize and disambiguate the notion of scale. A case in point: though today, references to ecology routinely evoke local communities, regions, and an entire planet in crisis, the concept of scale did not become popular in scientific circles until the 1970s.[9] Biologist John Wiens could write in the late 1980s that "'Scale' is rapidly becoming a new ecological buzzword," even while chiding fellow ecologists for being slow to adopt scalar thinking (relative to colleagues in physics, math, geography, and atmospheric and earth science).[10] Over two decades later, a recent literature review conducted by Brody Sandel and Adam Smith demonstrates that scale remains both poorly understood and applied as a variable in experimental design. As early as 2002, NASA researcher Jennifer Dungan and her coauthors recommended avoiding the word scale completely, in favor of more specific and universally agreed-upon terms.[11]

These scientific misgivings about scale are summarized in the following five cautionary principles, which in turn imply why games may embody a desirable alternative to actual experiments:

1 Scale operates at both spatial and temporal levels.

As Wiens notes in his early article in *Functional Ecology*, the inclination is to favor the spatial over the temporal or to examine the two aspects in isolation, rather than in tandem. Of course, such reduction flies in the face of the equally spatial and temporal complexity of human-wrought environmental change—from disrupted patterns of animal migration and biotic homogenization through globalization to chemist Paul Crutzen's dubbing of the current geological epoch as the Anthropocene.[12] Human agency is dramatically altering the very scale of events even as human perception has proven itself blind to catastrophic change that occurs in geologic time.[13]

2 Multiscalar analysis is better than monoscalar analysis.

Scientists also tend to design experiments confined to only one spatial scale, even though this limits the validity and generality of their findings. According to Sandel and Smith, scale is a "lurking factor" that frequently is not acknowledged or studied due to logistical constraints and the field ecologist's traditional reliance on the quadrat.[14] More resources must be expended to collect data at multiple scales, while restricting the "grain" (or unit size) and "extent" (or range) of one's experiment is always tempting because it reduces the number and impact of confounding variables.

3 We design experiments on anthropocentric rather than "effective" scales.

It probably comes as no great surprise that scientists usually design ecological studies on scales appropriate to human experience and perception, rather than the species or subjects in question. Yet ecologists Göran Englund and Scott Cooper, among others, explicitly warn against arbitrary and anthropocentric selection of scale. Instead, ideally, experimental design should involve "matching the scale attributes of organisms, processes, and the abiotic environment. Often this amounts to preserving the 'effective scale,' which describes the scale of the system as experienced by the organisms."[15]

4 We favor biotic, rather than abiotic, explanations.

Wiens suggests another problem directly related to anthropocentric design, namely ecologists' penchant for focusing on biological rather than physical processes. At smaller scales, we might reasonably expect biological interaction to dominate results, but at larger scales, factors such as atmospheric and geological effects could loom larger.

5 We assume continuity when discontinuity, or nonlinearity, is actually the norm.

> Perhaps the most important lesson from this survey of the ecological literature on scale is scientists' acknowledgement of nonlinearity or discontinuity as the governing principle of many natural states and processes. Essentially, one can never assume that what holds true at one scale will hold at another. Sometimes faulty statistical extrapolation and aggregation error are to blame, but, in general, Wiens reminds us, "the continuous linear scales we use to measure space and time may not be appropriate for organisms or processes whose dynamics or rates vary discontinuously."[16] He gives the example of insect diapause, one kind of animal dormancy in which certain species go into a period of growthless inactivity in response to unfavorable external conditions.

Why do these five closely linked observations regarding complex scale-dependence matter? In short, our tendency to select and measure at terrestrial, biological, and human scales and to describe phenomena as orderly and continuous series severely limits our understanding of nonhuman agency and experience. Depending on the scale of observation, too, the same factors may have differing "explanatory power."[17] The challenge then becomes moving past recognition of these issues to more responsible kinds of evaluation and engagement. As some ecologists have put it, how do we match large-scale questions and small-scale data, or "scale up" from "experimentally tractable scales" to the realities of expansive natural environments?[18]

Among the options available to us, those kinds of overzealous cartography intent on creating a one-to-one map of the world are the least appealing.[19] Far more intriguing are the varied media forms that dramatize scalar dependencies without sacrificing the capacity for wonder. Consider the whimsical Japanese game *Katamari Damacy* (2004), in which you play a tiny cosmic prince charged with rebuilding the universe by rolling up matter (Figure 12.1). Using a sticky "katamari" ball to pick up mass, you start with relatively small items but soon progress to larger and larger ones as the ball swells in size. Each shift in effective scale is signaled by a visual blurring, as the playable world stretches to new dimensions, and obstacles at one scale—hedges, pylons, and parking structures, to name just a few—become katamari fodder at another. Along these lines, *Katamari Damacy* cheekily invites us to raise our scalar consciousness to absurd heights, while literalizing the interconnectedness of all things. The game's title even translates to English as "clump soul."

Yet whether or not games like *Katamari Damacy* make available novel ways of conceptualizing the world and our place within it remains to be seen. Historically, other works have attempted to leverage new technologies of visualization to take

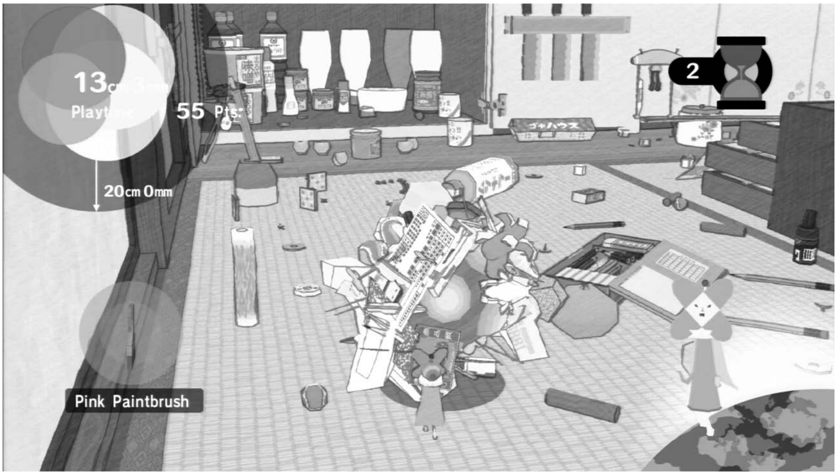

FIGURE 12.1 Rolling right along in *Katamari Forever* (2009) for the PlayStation 3, one of many games in the *Katamari* series.

the universe's measure with the same trademark curiosity, albeit a good deal more sobriety.

Exponential Vision and the *Powers of Ten*

In 1977, Charles and Ray Eames released the short film *Powers of Ten*, an approximately nine and a half-minute educational journey through space and the human body that uses the distinguishing framing device of an expanding and contracting white square, whose sides are determined by a power of ten, to demonstrate the differences in scale between astronomic and atomic levels of inquiry.[20] In its iconic opening scene, the film begins from a vantage point just a few feet above a man and woman picnicking by Lake Michigan in Chicago.[21] Looking down at the couple, as if pinned to the airy nothingness above them, the film gradually expands out to the then known boundaries of the universe (1,024 meters), then returns at accelerated speed to the blanket, only to plunge deep into the cells of the man's resting hand. Eventually, the film reaches the inverse magnitude of 10–16 meters, or the scale of an individual proton.

As enticing as it may be to dismiss the film as propaganda for the triumphal march of science, with its obsessively tidy vision and authoritative male narrator (the voice of physicist Philip Morrison), the bulk of the film notably takes place beyond the limits of unassisted sight, venturing deep into both conceptual and pictorial speculation. As such, the film testifies not only to a centuries-old scientific desire for all-encompassing observation but also the fundamentally imaginative character of scientific epistemology. Alex Funke, a key contributor to the

1977 film, described the production staff's creative protocol for dealing with the twin limits to knowledge and imaging as follows:

> In preparing for the film, we first sought out at every power the very best pictures available, then asked workers in that particular realm what we might see if the imaging were a hundred, a thousand times better. We had the raw material [. . .]. Then in each case *we made the imaging more than real* through adding, by hand, the details of what might (or should) be there.[22]

Like the atomic landscapes or topographical maps now produced by nonoptical technologies like the scanning tunneling microscope, many of the images used in *Powers of Ten* are less direct imprints of actuality than mediated constructions, or enhanced renderings of the real. At the macrocosmic scales, the film dissolves between artful composites of satellite and observatory photos and visualizations of data garnered outside the visible spectrum via radio, ultraviolet, and infrared astronomy; at the microcosmic scales, the film relies heavily on scanning electron and transmission electron microscopy, but also takes representational liberties. "When there were only mental models, we made physical ones," explains Funke.[23] Thus the film's pointillist depiction of a proton at the interior of a nucleus "is no photo but an abstract symbol of the physics we just begin to comprehend."[24]

Based on an illustrated, young-adult book by Kees Boeke called *Cosmic View: The Universe in Forty Jumps* (1957), and itself the model for numerous later adaptations, among them games and online applications,[25] *Powers of Ten* and its rapid history of permutation in many respects recapitulates the longer account of scientific vision outlined by historians of science Lorraine Daston and Peter Galison. The film not only attests to the idiosyncrasy and inventiveness of scientific vision, but within the relatively brief span of fifty years or so, the film, its immediate precursor, and its many successors also make evident the decisive effects of medium and time period on scientific visualization. Any such film, made today, would not only have to cope with the increased scale of astronomical and biological observation, but would also have to contend with images of city, planet, and cell that have since proliferated and grown more fraught. While the original *Powers of Ten* is an unapologetic paean to the scientific imagination, depicting a world where couples lounge contentedly near "bustling" freeways, seemingly sandwiched between two wondrous worlds of undiscovered matter, the intervening decades have borne witness to growing environmental concerns and fears. A modern audience shown aerial views of Lake Michigan, Chicago highways, and the troposphere might be more likely to associate them with the invasive zebra mussel, automotive congestion, and greenhouse gases than with idyllic summer relaxation. Similarly, peering into the recesses of the cell and the atom today is likely to conjure debates over genetic modification, cloning, and nuclear energy—the common litany of post–World War II anxieties over the nature and extent of scientific progress.

Furthermore, given the pace of scientific and technological innovation since the film's original release, *Powers of Ten* belongs to a now bygone era of exceptional visualization. In the late 1960s and early 1970s, when astronauts on various NASA Apollo missions took some of the first full-view pictures of our planet from outer space, several of the resulting images, most famously the "Blue Marble," became icons of the nascent environmental movement.[26] In that historical period, one noticeably less saturated by satellite imagery, the sight of Earth suspended in the void of space highlighted the planet's singular fragility. Since 2005, however, satellite imagery of the Google Earth variety has become a staple of daily media use, moving beyond government, particularly military usage, to become the quotidian basis for everything from maps and driving routes to weather and traffic monitoring. In the contemporary moment, *Powers of Ten* loses much of its initial novelty, for now anyone with a smartphone or broadband-enabled computer can replicate the film's visual maneuvering from the terrestrial to the atmospheric.

Yet *Powers of Ten* captures a pivotal moment in the history of scientific visualization, in its bypassing of traditional print media in favor of cinematic animation. In the volume that followed the film, Eames supporters Philip and Phylis Morrison emphasized the superiority of the moving over the still image:

> No visual model can convey unaided the full content of our scientific understanding, the less if it is restricted to the static. [. . .]. The limitation of the static image is not simply that it lacks the flow that marks our visual perception of motion: Real change in the universe is often too slow or too fast for any responses of the visual system. The deeper lack is one of content. A single take belies the manifold event.[27]

For the Morrisons, the advantages of film and its fledgling companion video derive from their capacity to present not only movement, but also change over time, leading them to conclude in this same passage that "Film and the video processes together constitute the most characteristic form of art in this changeful period of human history."

From our vantage point in the new millennium, we might well wonder what the Morrisons (not to mention the Eameses, who were well known for their interest in toys) would have made of video games, media that were still in their infancy at the time of the film's 1977 release. Could a game capture "the manifold event" even more readily than the conventional moving image? If so, would games then constitute the most characteristic form of art in this changeful period of human history?

"Your Personal Universe in a Box"

> Tired of your planet? Build a new one as you embark on the most amazing journey ever.
>
> —Spore packaging

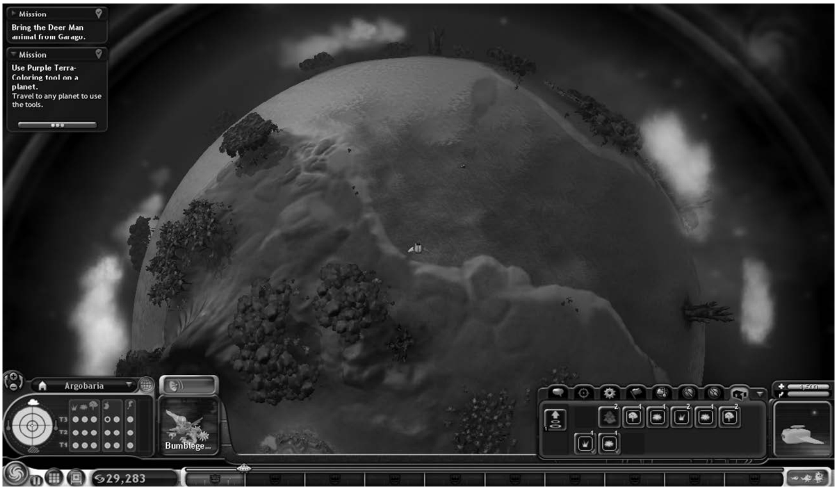

FIGURE 12.2 A spaceship (center) hovers over a planet's surface in *Spore*'s final stage (author screenshot). **AUQ31**

Developed by game luminary Will Wright and the studio Maxis, and published by Electronic Arts (EA) in 2008, *Spore* was ambitiously touted as an evolution-simulation game featuring five stages of species development: cell, creature, tribe, civilization, and space (Figure 12.2). Historically speaking, *Spore* represents the culmination of nearly two decades of Wright's work in the game industry, most of it on *Sim* games like *SimCity* and *The Sims*. The collective *Sim* games conveniently suggest something of Wright's broad-ranging fascination with environmental modeling, in their unresolved tension between an emphasis on environmental or biocentric concerns—how to manage a planet, an ant colony, an urban landscape—and an equal anthropocentric fascination with how the agents within those landscapes carry out their lives. In visual and experiential terms, the various *Sim* games also represent different points on a scale of magnification, from the global perspective of *SimEarth: The Living Planet* (1990) and the metropolitan perspective of *SimCity* (1989) to the neighborhoods and single-family dwellings of *The Sims* (2000–present) and the backyard dirt colonies of *SimAnt* (1991). However, *Spore*'s clearest predecessor in the *Sim* franchise is *SimEarth*, which invites players to supervise evolutionary scenarios running the gamut between open-ended experiments and theoretically pre-scripted paradigms like the "daisyworld" proposed by Andrew Watson and James Lovelock, in which the world and its inorganic and organic actors are posited as a holistic, self-regulating entity greater than the sum of its parts.[28]

Graced with all the computational and graphical advantages of the intervening nearly twenty years, *Spore* appears to offer an unprecedented level of virtual ecological detail. One could easily spend hours within the game's Creature

Creator, shaping one's image of the ideal species, and the game unobtrusively enfolds aspects of sciences ranging from geology, zoology, and ecology to climatology and astrobiology. Gameplay in the space phase, in particular, touches on long-cherished environmental principles like ecosystem stability and habitat renewal. For instance, one of the primary tasks of the stage is to render environmentally challenged planetoids hospitable enough for colonization, which requires substantial attention to both climate and species diversity. Players also carry out missions, some of which deal overtly with environmental crisis, such as the alarming directive, "Save planet *X* from ecological disaster!"

On the one hand, these tasks helpfully entreat the player to take on the mantle of environmental steward for colonized worlds; on the other, the espoused version of ecological care drastically oversimplifies life's complexity and threatens to perpetuate the myth that humans can exercise surgical precision in diagnosing and addressing environmental ills. Saving a planet, it turns out, often means hunting down and violently exterminating "infected" organisms using your spaceship's onboard laser. Restoring balance to an ecosystem translates into filling vacant animal or plant niches in a planet's food chain via the indiscriminate abduction of species from other planets. Even planetary climate correction becomes almost trivial given the ready availability of futuristic tools. Not enough atmosphere? Not a problem—toss an atmosphere generator at the planet surface and watch clouds of reassuring-looking gases drift into the troposphere. Climate too chilly? Rain a toasty meteor shower down on the world or apply a heat ray to begin a warming trend. Using weapons-grade lasers, high-tech rays, and elaborate mechanical gizmos to bludgeon a planet's climate into shape makes a mockery of the delicate "butterfly effects" espoused by chaos theoreticians to describe the extremely sensitive dependence of final states on even seemingly unrelated or minor initial conditions. In sum, *Spore* does pose ecological lessons, but those lessons verge on environmental slapstick.

Not surprisingly, after the game's much-heralded release scientists quickly realized that *Spore* had fallen short of its advertised marks. *Science* magazine's John Bohannon called the game a massive disappointment in terms of its potential for science education, even after granting that its primary aim was to please rather than inform. After playing *Spore* with a team of scientists to evaluate its scientific merits, Bohannon ultimately flunked the game, lamenting that it got "most of biology badly, needlessly, and often bizarrely wrong," particularly in its treatment of evolution.[29] Two of the scientists who helped to assess the game, evolutionary biologists Ryan Gregory and Niles Eldredge, similarly concluded that "*Spore* is essentially a very impressive, entertaining, and elaborate Mr. Potato Head that uses the language of evolution but none of the major principles."[30] Foremost among *Spore*'s many evolutionary inaccuracies is the complete lack of consequence for player death! *Spore*'s much ballyhooed version of evolution is, in fact, closer to the long discredited theory of Lamarckian evolution (in which an individual organism can develop and pass on adaptations during its lifetime) or evolution's creationist-tending nemesis, intelligent design (where players are the universe's unseen architects). In the eyes of scientists, *Spore* deploys evolution primarily as a marketing gimmick; the theories of genetic succession are less the guiding force for actual game mechanics than rhetorical trimming around the digital dollhouse play for which Wright has become famous.

In comparing *Spore* to a glorified Mr. Potato Head, Gregory and Eldredge acknowledge that the protracted, random nature of real evolution is noticeably at odds with the logic of immediate customization that makes *Spore* so attractive. The game's versatile Creature Creator software has arguably proven more popular than the game itself; it is a feature, or a subgame, that threatens to render the rest of the game a mere showcase for the well-crafted avatar. In a similar fashion, the bulk of the game's command interface attends to matters of aesthetic preference. Should you find yourself displeased by the lumpy contours of your planet or its dull sandy color, you can use special tools to level terrain, form "cute" canyons and crystalline mountains, or turn the sea purple, the atmosphere red, and the land cyan. Incredibly, none of these changes seems to affect life on the planet, implying at some fundamental level that cosmetic alteration need not affect environmental health. Like the Creature Creator, which essentially equates evolution with deliberate customization in a digitally enhanced production mentality at odds with the vagaries of actual evolution, *Spore*'s building-, vehicle-, and planet-design menus emphasize the malleability of matter, not so much its ontological essentialism as its receptivity to the expression of individual preference.

Criticisms like these reveal an unavoidable tension in using games to model environmental processes—the necessary give-and-take between player freedom, or agency, and ecological constraint. The worlds that Wright creates tend to be sandboxes more than slides, that is, open-ended systems inviting experimentation rather than goal-oriented spaces centered on measurable achievement. Reviewers and players disappointed by *Spore*'s lackluster gameplay have therefore sometimes generously allowed that *Spore* is less a game than a software toy, and Wright himself has called *Spore* a "philosophy toy," designed to lead younger generations to insights via self-directed investigation.[31] At the same time, *Spore*, like most of Wright's games, is recognizably a "God game," meaning that players act as omnipotent beings whose every action influences the universe in which they operate. Tellingly, Wright has said that he wanted players of *Spore* to feel like George Lucas, not Luke Skywalker—that is, the architect of fantastic worlds rather than an individual within them. *Spore* accordingly reflects Wright's valorization of human agency and intentionality. From an environmental standpoint, *Spore* models the strain between envisioning nature as either a design space or a problem space, or a place of invention and expression versus an arena fitted with recognizable troubles and solutions.

While it might be tempting to read *Spore* as an exercise in frivolous and, in the end, noncommittal play, Wright has publicly vaunted the game's potential to underscore environmental objectives. During his demo of *Spore* to TED

Conference participants in March 2007, Wright used his in-game spaceship to pump huge amounts of carbon dioxide gases into a planet's atmosphere, thereby raising its ocean levels, swamping his own cities, and increasing the temperature of the planet to a point where the oceans evaporated and the surface burst into flame—clearly not a winning strategy so much as a curiosity-driven experiment. Having done this, Wright casually remarked:

> What's interesting to me about games in some sense is that I think we can take a lot of long-term dynamics and compress them into very short-term kind of experiences, because it's so hard for people to think fifty or a hundred years out, but when you can give them a toy and they can experience these long-term dynamics in just a few minutes, I think it's an entirely different kind of point of view, where we're actually mapping, using the game to remap our intuition. It's almost like in the same way that a telescope or microscope recalibrates your eyesight. I think computer simulations can recalibrate your instinct across vast scales of both space and time.[32]

Wright thus asserts that games can act as intellectual and spatiotemporal prostheses, in language heavily reminiscent of Marshall McLuhan's contention that media act as extensions to humankind. *Spore* evidently has the power to reveal to us the dramatic consequences of our current follies, here the overproduction of greenhouse gases that trap the heat of the sun's rays and lead to global warming. But what may be more important is the residual impression that environmental catastrophe of this sort is neither unforeseeable nor inevitable.

Unlike the iterations of a purely scientific model or the preset narratives of film or science fiction, a game like *Spore* offers both repetition and difference, as directed by the personal choices of the player—what gamers would call replay value. *Spore*, which by design has been freed from the constraint of a single "win state," opens up an ethically unencumbered space in which players can spool out countless environmental futures, from pastoral empires to admittedly morbid fantasies of ecological disaster. Put more broadly, what *Spore* perhaps does best is it gives players the ability to experience and affect procedural change at scales ranging from the microscopic to the galactic and from the short- to the long-term, effectively heeding the scalar warnings of ecologists. The game's deliberate open-endedness forces players to ponder the benefits and drawbacks of interaction at each level. Like scientists who study and model real-world environments, players in virtual worlds may find themselves struggling with a similar set of questions: what is the value of remaining at one scale, and when is it necessary to move beyond that scale to examine the relations or transgressions that occur across the artificially imposed boundaries of hierarchical thinking?

The effective visualization of ecological states at a range of scales has become crucial, given contemporary environmentalism's trouble with representing largely intangible problems and its internal frictions between what we could call the microenvironmental and macroenvironmental approaches to pressing ecological problems. Although games inevitably participate in flows of material and capital and so-called attention economies that place them squarely within the ongoing debate over local, as opposed to global, modes of thinking and living,[33] digital games can obviate the perceived choice through multiscalar play. Both Ursula Heise and Timothy Morton have suggested that environmentalists have lost sight of the large-scale nature of environmental challenges in their well-intentioned espousal of place. Heise wonders about the aesthetic possibilities of a deterritorialized environmental vision, while Morton exhorts us toward expansive, even cosmological thinking. The local and the global are, after all, only imagined extremes, beyond which lie countless microorganisms, elementary particles, and most of the known universe. If we could, like a Sporovian spacecraft, escape the anthropomorphic drag of the local-global dualism, perhaps our earth-friendly bumper stickers would urge us to Think Galactically, Act Microscopically.

Playing the Game of Nature

As unorthodox as the thought may be, video games may be even better suited to scientific visualization than the conventional moving but noninteractive image,[34] and support for such a proposition may be found well outside the bailiwicks of game scholars and educational software developers. Daston and Galison, and Colin Milburn, for example, have independently identified the same trend in scientific imaging—away from depiction toward fabrication, at a point where the formerly distinct boundaries between recording and producing have been breached. For my purposes, the value of what Milburn, Daston, and Galison believe to be a recent paradigm shift from ocular to tactile science, or perhaps the unexpected convergence of visual and haptic epistemologies, lies in its evident recapitulation in less rarefied media contexts. Well outside the elite research laboratory, in millions of ordinary living rooms and home offices, computer and video games have popularized the same qualitative shift beyond vision toward interactivity, in roughly the same period (as Milburn chronicles, nanotechnology flourished from the 1980s onward). The player of a game like *Spore* is thus akin to the archetypal scientist of the latest representational epoch described by these authors—one who melds creativity and intuition with the efforts of instrumental science.[35]

Games are not easy solutions to vexing scientific problems or palliative alternatives to real-world action, but there are felicitous similarities between gameplay and ecological work. In fact, the same ecological literature that earlier outlined the difficulties with scalar modeling also reveals some of these foundational correspondences. First, all games are at some level exercises in controlled experimentation, or what ecologists would call "perturbation experiments," meaning that some factor is manipulated in certain units while other units are left as unmanipulated controls. By necessity, too, both ecologists and game designers must distill the richness of real-world systems into manageable experimental structures through modeling and dimensional analysis, though perhaps only ecologists feel they must account for the effects of the reduction in complexity. A third method that scientists within and beyond ecology use to reconcile scales, which has several counterparts in games, is ground-truthing. Ground-truthing refers to observations made, usually on land, which are then applied to calibrate remote-sensing devices like satellites through confirmation or denial of their measurements. Players of games regularly engage in a kind of ground-truthing when they consult overhead mini-maps or other navigational aids, and a growing number of alternate-reality games and GPS/GIS-based activities like geocaching also explicitly meld game fiction with investigations at actual coordinates.

In one area, however, games are far better suited to ecological modeling and experimentation than actual scientific studies—namely, system breakdown. Working ecologists cannot destroy or arbitrarily change real-world environments without very good reason, and often they must opportunistically wait for events like fires and oil spills to study things like ecosystem response to extreme conditions. In games, quite the opposite holds. The ludic impulse encourages sometimes methodical, sometimes rambunctious trial and error, and in some games, disasters, both natural and manmade, are only a click away. In some ways, this extends the insights in Jesper Juul's recent volume on the art of failure in video games to suggest that failure can be seen not just in the sense of personal fault that Juul dwells on, but also the kind of systemic failure we invoke when speaking of unhealthy bodies or ecological units.[36] For now, we might tentatively call these four modes of ecology-game crossover experimentation, modeling, verification, and failure, all of which demand thoughtful interplay between scales, players and designers, and environmental experience and speculation. *Spore*'s modest successes in this area owe much to the influence of *Powers of Ten*, not least because *Spore* embeds its player in neatly nested experimental domains, treating developing life at successive orders of magnitude, from the microscopic to the macrocosmic. Wright also pays unmistakable homage to the film in the game's culminating space stage, by allowing players to control in-game perspective through the use of their mouse wheels—scroll the wheel forward and your spaceship descends from orbit through layers of atmosphere to the chosen planet's surface, where you can skim the ground to search for native flora and fauna or engage city populations. Scroll the wheel backward and your spaceship lifts off and returns to the microgravity of outer space. Keep scrolling, and the game perspective widens from planet to solar system and finally to the entire galaxy, where in much accelerated time, you can watch spinning celestial arms crammed with the twinkling lights of dying stars.

Unlike viewers of *Powers of Ten*, however, *Spore* players may navigate between these different scales at will, guided by such sundry motivations as curiosity, goal-oriented achievement, aesthetic preference, or perhaps even morbid or whimsical brands of environmental schadenfreude, as when Will Wright nonchalantly destroyed a game planet for his TED conference audience. In ecological jargon, we might also designate game environments or virtual worlds as mesocosms, that is, arenas of a size usefully intermediary between field experiments and laboratory conditions. Like portions of a field sectioned off for study, or partially enclosed waters, game ecologies toy with select variables within environments that remain close to but apart from life. The best games, like the most successful ecological experiments, tread a fine line between bounded tidiness and inclusive reality, heightening our awareness of mechanism while providing ample outlets for our energy and curiosity. Games are inherently multiscalar—melding the quantitative and the qualitative, the experiential and the analytic, the computational and the graphical—and a universe of questions awaits.

Notes

1 "Professor Emeritus Al Bartlett—Physics at University of Colorado at Boulder—Articles on Exponential Growth, Peak Oil and Population Growth, Sustainability, Renewable Resources and the Environment," http://www.albartlett.org/ (accessed June 30, 2015).

2 Willard McCarty, "Modeling: A Study in Words and Meanings," in *A Companion to Digital Humanities*, edited by Susan Schreibman, Ray Siemens, and John Unsworth (Oxford: Blackwell, 2004), para. 3, http://www.digitalhumanities.org/companion/ (accessed September 29, 2014).

3 From Dr. Seuss, *The Lorax* (New York, NY: Random House, 1971). Over the years, environmentalists' have had decidedly mixed attitudes to the so-called population problem, including the many uses and abuses of Thomas Malthus's *Essay on the Principle of Population* (1798), Garrett Hardin's "The Tragedy of the Commons" (1968), Paul Ehrlich's *The Population Bomb* (1968), and Alan Weisman's *Countdown* (2013). Often, "scale" is a tempting euphemism for optimum population, or sustainable human numbers.

4 See Timothy Morton, *The Ecological Thought* (Cambridge, MA: Harvard University Press, 2010), 1. For Morton, hyperobjects are "things that are massively distributed in time and space relative to humans" and therefore impossible to grasp in their entirety, such as radiation, black holes, and global warming.

5 Unfortunately, ecology's overuse by ordinary people, well-meaning environmentalists, and diverse academics has evacuated it of its original, largely scientific meaning. Ecology textbooks today bear little imprint of previous and ongoing contests over its scope and meaning, while everyday use of the term has transformed it into a flaccid descriptor connoting everything from interdependence to the study of all things natural. For more on ecology's history and its ties to cybernetics, see the chapter by Erica Robles-Anderson and Max Liboiron in this volume.

6 Ralph Waldo Emerson, "Nature," in *The Collected Works of Ralph Waldo Emerson, Volume I: Nature, Addresses, and Lectures*, edited by Robert E. Spiller and Alfred R. Ferguson (Cambridge, MA: Harvard University Press, 1971), 32.

7 Edward R. Tufte, *The Visual Display of Quantitative Information* (Cheshire, CT: Graphics Press, 2001).

8 For the latter, see Chris Tong, "Ecology without Scale: Unthinking the World Zoom," *Animation*, 9, no. 2 (2014): 196–211. Tong recommends jettisoning scalar models because they reify unfortunate spatial and classificatory hierarchies.

9 According to Brody Sandel and Adam B. Smith, although they first find the more specific search phrase "spatial scal*" in an article from 1987. See Sandel and Smith, "Scale as a Lurking Factor: Incorporating Scale-Dependence

in Experimental Ecology," *Oikos*, 118, no. 9 (2009): 1284–1291, doi:10.1111/j.1600–0706.2009.17421.x.

10 John A. Wiens, "Spatial Scaling in Ecology," *Functional Ecology*, 3, no. 4 (1989): 385.

11 J.L. Dungan, J.N. Perry, M.R.T. Dale, P. Legendre, S. Citron-Pousty, M.-J. Fortin, A. Jakomulska et al., "A Balanced View of Scale in Spatial Statistical Analysis," *Ecography*, 25, no. 5 (2002): 626–640.

12 Technically speaking, we still live in the Holocene, although the Anthropocene has attracted numerous adherents. In fact, Erle C. Ellis and Navin Ramankutty argue that humans have had such a tremendous impact on the Earth's surface that we should now think in terms of "anthromes" rather than climate- and vegetation-defined biomes. See Ellis and Ramankutty, "Putting People in the Map: Anthropogenic Biomes of the World," *Frontiers in Ecology and the Environment*, 6, no. 8 (2008): 439–447.

13 Consider Paul Martin's prehistoric overkill (of megafauna) hypothesis, described in Elizabeth Kolbert, *The Sixth Extinction: An Unnatural History* (New York, NY: Henry Holt, 2014), 231–232.

14 A quadrat is a sampling plot typically measuring around 1 square meter.

15 Göran Englund and Scott D. Cooper, "Scale Effects and Extrapolation in Ecological Experiments," *Advances in Ecological Research*, 33 (2003): 170. This idea of effective scale recalls early naturalist philosopher Jakob von Uexküll's theories about organismal time and space, most notably captured in his description of the tick. See Jakob von Uexküll, *A Foray into the Worlds of Animals and Humans*, trans. Joseph D. O'Neil (Minneapolis: University of Minnesota Press, 2010), 44–52.

16 Wiens, "Spatial Scaling in Ecology," 389.

17 Englund and Cooper, "Scale Effects and Extrapolation in Ecological Experiments," 170. For instance, some influences that figure largely at small scales, like experimenter disturbance or predation, decrease and grow almost negligible at very large arena sizes, in what Englund and Cooper call an asymptotic or logistic relationship.

18 N. Underwood, P. Hambäck, and B.D. Inouye, "Large-Scale Questions and Small-Scale Data: Empirical and Theoretical Methods for Scaling up in Ecology," *Oecologia*, 145, no. 2 (2005): 177–178.

19 I cannot help but think of Jorge Luis Borges's "On Exactitude in Science," in *Collected Fictions*, trans. Andrew Hurley (New York, NY: Penguin, 1998). Borges's notoriously pithy story could be fruitfully applied to many contemporary projects, from genome sequencing to database-driven big-data initiatives.

20 A shorter, black-and-white "rough sketch" of the film was released in 1968, made for the Commission on College Physics. The 1977 color version was funded by IBM.

21 In actuality, the live portion of this memorable picnic scene was filmed in Los Angeles, for greater production control. The picnic scene in the 1968 sketch took place in Florida.

22 Philip and Phylis Morrison and the Office of Charles and Ray Eames, *Powers of Ten: A Book about the Relative Size of Things in the Universe and the Effect of Adding Another Zero* (New York, NY: Scientific American, 1982), 145 (my emphasis).

23 Morrisons, *Powers of Ten*, 145.

24 Ibid., 101.

25 The film has inspired many reincarnations, for instance the artists' collective Futurefarmers' *A Variation on the Powers of Ten* and Cary and Michael Huang's web-based applications *The Scale of the Universe* and *The Scale of the Universe 2*.

26 Most notably, Stewart Brand lobbied for the release of these planetary images and used them on a number of the covers of his counterculture magazine, *The Whole Earth Catalog*, published between 1968 and 1974.

27 Morrisons, *Powers of Ten*, 8.

28 The daisyworld theoretical models attempted to provide support for Lovelock's Gaia hypothesis by demonstrating that the population behavior of living species (in this case, black or white daisies with different albedos, or reflective properties) could explain the

planet's apparent ability to regulate its own atmospheric and surface temperatures in response to varying solar luminosity.

29 John Bohannon, "Flunking *Spore*," *Science*, 322, no. 5901 (2008): 531.

30 Ibid.

31 Will Wright, "*Spore*, Birth of a Game" (presentation, TED2007, Monterey, CA, 9 March 2007).

32 Ibid.

33 Many environmental specialists, among them Lowell Monke, David Sobel, and Mitchell Thomashow, have expressed serious misgivings about digital media, aligning them with a distracted inattention to lived space.

34 A worthwhile point of comparison would be the viral "molecular movies" described by Bishnupriya Ghosh in this volume.

35 See Lorraine Daston and Peter Galison, *Objectivity* (New York, NY: Zone Books, 2007), 46; Colin Milburn, *Nanovision: Engineering the Future* (Durham, NC: Duke University Press, 2008). In Daston and Galison's words, "practitioners of trained judgment professed themselves unable to distinguish between work and play—or, for that matter, between art and science. [. . .] surrendering themselves to the quasi-ludic promptings of well-honed intuitions." Milburn's nanotechnology professionals are no exception; some of the most iconic images to emerge from nanoscience have had less to do with function and "serious" research than an artistic sense of play, for example, Donald Eigler and Erhard Schweizer's now-famous creation of the IBM logo using xenon on nickel.

36 Jesper Juul, *The Art of Failure: An Essay on the Pain of Playing Video Games* (Cambridge, MA: MIT Press, 2013), 45.