Is Vertical Farming a Viable Proposal?

BIOS 2010 Dissertation
Candidate Number: 26902
Total word count: 10,053

Methods:

Vertical Farming is a biotech proposal that has received increasing amounts of attention in scientific, media, and political circles, but a sociological/STS analysis has not been attempted to date. When I began this project, I imagined that the research would be quite focused. However, what I found is that in investigating food systems and Vertical Farms (VFs), a convoluted and complicated picture began to emerge that includes local and global politics, health, capitalism, citizenship, governmentality, environmental degradation, global warming, ecology, biology, genetics, population, urbanism, biotechnology, synthetic biology, bio-value, and new concepts of "nature" and "natural." All of these areas were very worthy of expansion and I have tried to provide as much information as possible, while also respecting the limits of the assignment.

In order to research this question, I conducted a literature review to understand the different ways that VFs are being discussed in the media and in scientific circles. However, the net had to be cast even wider to understand the ways that VFs fit into a larger narrative about global warming, population growth, environmental degradation, sustainability, biotechnology and biological control. Therefore, my research also included public lectures, documentaries, and radio pod-casts. In sum, the research and information about VFs themselves was pulled mostly from the popular media, while the theoretical components (biological control, ANT, imagined futures, etc) was pieced together in reading books and articles from different theorists and writers including James Lovelock, Bruno Latour, Nikolas Rose, Adele Clarke, Sarah Franklin, Elizabeth Kolbert, Steven Brand, and William Cronon.

I also conducted three interviews in late 2009 and early 2010. The purpose of these interviews was to fill gaps of knowledge, and also raise some more theoretical questions that occurred to me as I was researching. Again, (to my knowledge) there has not been a sociological study of Vertical Farming to date. Much of the VF literature used in this research was mostly found in the popular media. These sources often provided solid information, but did not engage in a level of analysis that is needed for this type of research project. The three interviews were with Dr. Dickson Despommier, who originally thought conceived of VFs, his main research assistant Mr. Jake Cox, and Mr. Jonathan Fisher (See *Appendixes C & D* for interview transcripts and notes). My questions for both Despommier and Cox highlighted areas that were not covered in any literature I could find. Furthermore, being that I had a vague idea about areas that I would critique Vertical Farming, I also wanted to pose questions that would allow Despommier and Cox to defend their idea.

Currently, VFs lack the necessary funding to become a reality and I wanted to understand why money was hard to come by. Mr. Fisher is a hugely influential US based venture capitalist currently making investments in green and alternative technologies. The main purpose of this interview, therefore, was to gauge the reaction/perspective of an investor to the idea of VFs. The interview with J. Fisher had to be conducted by phone, and therefore recording device was not used. However, the notes from this interview are included in Appendix D.

Abstract: *Over the next 50-100 years, complex problems such as global warming, population growth, increased urbanization, decreased water supply, and insufficient arable land are projected. Should these global problems become realities and intertwine, a new way of thinking and managing humanity, civilization, and the planet itself will be essential. Vertical Farms are a biotech proposal that would bring farming back into the center of big cities in skyscraper farms, leaving the countryside to nature to restore itself. The goal of this research is to analyze VFs as a biotech proposal and also to situate it within a new "style of thought" (Rose, 2003: 16-17) and new philosophy about the scale of biological control. While VFs are a difficult idea to critique, especially in light of all the aforementioned problems, this essay also discusses the ways in which Vertical Farming is a techno-scientific solution to a series of social/cultural problems, and areas where the idealized narrative surrounding Vertical Farming could over look some fundamental problems. In order to clearly address all these issues and provide an in-depth analysis, an extensive literature review was conducted over several months, as well as 3 interviews. One interview was conducted with Dr. Dickson Despommier (the visionary behind VFs) and another with Despommier's main research assistant, Jake Cox. The final interview was with John Fisher, a successful and influential US venture capitalist, to understand whether VFs present an appealing opportunity for investment. Ultimately, what I have aimed to show how VFs are not just a biotechnology proposal, but also part of a sociological and cultural process that will force humans to rethink their role and place within a wider Life sustaining system that is Earth.*

Sitting down, it really feels like any other restaurant and I cannot tell if I feel relieved or disappointed. The menu is full of choices for all categories of eaters – omnivore, vegetarian, vegan, flexitarian – but rather than the food coming from local farms in upstate NY, California, Israel, or Mexico, it comes from the 30 floors above me. The waitress comes over to fill my water glass, "Can I tell you about some specials today?" Shoot. She goes through a few unsurprising plates – a soup, salad, and a hand made pasta- but then she says something pretty intriguing, "We also have some things from the lab, if you interested?" Yes, please. "Well, we have two new varietals in the techs are working on: One is a string bean, snow pea hybrid, radish hybrid – it's got great crunch and a really punchy flavor; that is served with a tahini sauce with almond and pumpkin seeds. And the other is a Sweet Potato/Tomato Hybrid. It has retained its sweet potato texture, but the color is deeper red and the taste is more tart and really interesting. That is served on bed of sautéed spinach with a dash of sweet onions and fresh corn breadcrumbs. I would highly recommend it."

Over her shoulder, I see a huge cart of corn being wheeled through the hallway, followed by carts of tomatoes, potatoes, and lettuce. Then it hits me, this is no regular restaurant - this is a Vertical Farm, and it is changing the city and its citizens in profound ways.

There are several throughout NYC, each with its own "flavor", if you will. The one I am dining in is located in the Meat Packing District, and the crops that are being grown in the 30 floors above me are vegetables common in supermarkets including salads, herbs, corn, potatoes, wheat, tomatoes, avocadoes, fruits, etc. However, added to the thrill of knowing that your food comes from a skyscraper farm in lower Manhattan is also a profound sense of relief, knowing that your mid-December craving for avocado salad can be satiated without tons of carbon being spewed into the atmosphere.

The two other Vertical Farms (VFs) currently operating in NYC employ the same hydro and aeroponic techniques for growing crops. The one based in China-town acts as a cultural exchange center, and therefore focuses on typical Chinese fruits and vegetables. The third Vertical Farm, located at 42nd street, is the "educational farm" where people are given tours to explain how VFs work, can be trained to work in the "fields", or take cooking classes. A friend, who went on the tour and opted for the tour/meal combo, reported that he was enjoying the experience up until they got to look at the top floors where chickens were being raised. He explained, "Don't get me wrong, the chickens looked happy enough. They had panoramic views of Manhattan, plenty of sun light, they were foraging, and had lots of space of walk around. But then we were allowed to 'choose our chicken' kind of like you do with lobsters in seafood restaurants. Next thing I knew, I had turned around and changed my request to a vegetarian meal." Another friend's five-year-old daughter had taken the same tour on a school field trip and she told me, "chickens make eggs. I didn't know that before" (Hernandez, 2009). And some would argue that is part of the beauty

of VFs: It 's an educational tool that makes our food production visible, at the very center of our cities. As Dickson Despommier, the Columbia University Professor who dreamed up Vertical Farms has written, "The Vertical Farm is not merely about food, but about the unseen circuits of energy and materials, labor and resources, capital and infrastructure, technology and politics upon which our cities depend" (Despommier and Ellingsen, 2008: 27).

All dreaming aside, VFs do not yet exist. However, VFs are a biotech proposal that are gaining increasing attention among scientists, architects, and city politicians in the face of complex problems like global warming, fossil fuel intensive farming techniques, agricultural run-off, environmental degradation, limited fresh water supplies, population growth, and a projected 80% of the world's population moving into cities by 2050 (Brand, 2009: 26). VFs would produce crops in a completely human controlled environment, using hydroponic irrigation technologies (*see Appendix A*), which would drastically reduce the amount of water used for feeding plants (up to 70% less). VFs would also effectively shield the food supply from increasingly unpredictable weather patterns due to global warming, as well as any viruses that can attack crops in the field. Being that all the crops would be enclosed, controlled, and protected, VFs would also almost completely eliminate the need for fossil fuel intensive techniques, including the use of petro-fertilizers, herbicides, or pesticides. VFs could even obviate the need for GM crops/seedlings of any kind, meaning that all crops grown in VFs could theoretically be organic. Furthermore, all food distribution would essentially become "local", eliminating carbon emissions produced when, for example, transporting citrus fruit from Mexico to NYC in the dead of winter. In my interview with Jake Cox, a graduate student working on VFs with Despommier, he explained, "The VF is the nexus of food, energy, and water problems… It's a holistic approach to all these city planning issues that have been only been tackled one by one." And, should the idea become a reality,

it would also be the first time that food production is completely removed from planetary processes to become human controlled.

In late 2009, I went to visit Despommier at his office in upper Manhattan at Columbia University's Mailman School of Public Health. He is engaging, friendly, talkative, and is clearly energized by the prospects of his idea and the increasing attention it is receiving from the media, public officials, and even governments around the world (including the USA and France). He excitedly told me:

> "As a result of (the Op-Ed) I wrote in the NYTimes (Summer 2009)… I got a call from the White House, from this guy by the name of Alfonso Carrion, who used to be the Borough president for the Bronx and he is now the Department of Urban Affairs Chairman of the Obama Administration. He called me immediately and said 'This is just exactly what we need to do. This is a long-term solution to this problem. We need to do it.'… and I told him 'What took you guys so long?'

Presently, 38% of the total landmass of Earth is dedicated to agriculture (Encyclopedia of the Earth: 2008). With current population projections, it would take a landmass the size of Brazil to adequately feed the growing world, but this is arable land that the planet simply does not have (Fischetti: 2008). Furthermore, "it took some 10,000 years to expand food production to the current level of about 5 billion tones per year. By 2025, we will need to nearly double current production again" (Borlaug, 2000: 6). Hence, VFs could also be a solution to increasing food supply in less time, under deliberately controlled conditions to increase yields, and producing crops year round. As Despommier said in our interview, "All of these things that are totally uncontrollable outdoors are totally controllable indoors."

Food, at least in the Western world, is of such abundance that one rarely stops to think about where it comes from, or how it got there. In a recent LSE public lecture (November 29, 2009), Richard Sennett discussed this as *de-*

materialization or "*dematerialized consumption*." Sennett's primary argument referred to the consumption of clothes or objects, but it can also be extended to food because in both cases people have "no idea how things are made or what they are consuming."[1] Paradoxically, the more we consume, the less we are aware of how or where these objects come from. This last point can is most salient in off-season foods that are in supermarkets year-round. Most people don't even think about how these crops were grown, where they come from, or how they got from the farm to the market.

In recent years, however, there has been more media and public attention on "linking farming policy to a host of global factors…(including) health (which) has become a complicated site of governmentality" (Franklin, 2001: 6). This last point is especially visible in health issues like obesity and diabetes, which have been linked to food choices but are not dealt with at the level of agricultural reform. In other words, the governing of peoples' food/health issues are not dealt with at a level where there could be systemic change – that is, the reformation of agricultural policies or local/global food systems - but instead is dealt with by attempting to control and manage the negative effects of broken systems (i.e. the negative health effects). However, in recent years people have become more aware of the impact their food choices and "the call to forge deeper connections with the food we eat has pulled thousands to the nation's farmers' markets, sprouted a million backyard seedlings" (Farrell, 2009). This new interest in food has manifested the infant urban agricultural movement, which has sprung food co-ops, community and private gardens, and green roofs.

While this research will focus on mostly on plants, VFs also could potentially provide solutions for meats production as well. In a 2006 paper

[1] Quote taken from Sennett LSE public lecture, "Cities, Design, and Climate Change" (Nov. 29, 2009).

written by the UN FAO, it was reported that, "the world's meat industry produces more green house gases (GHG) than all sources of transportation, specifically cars" (Lobrano: 2009). In recent years, there has been increasing scrutiny in the media regarding the wastefulness of current industrial meat production practices, as well as the negative impacts on land, water, and even human health (not to mention the conditions the animals are forced to endure). Scientists have also predicted that if rate of fishing continue at this rate "we will see the end of most seafood by the end of 2048" (Murray, 2009). There is even a direct connection between current farming practices and seafood declines as, "all of the estuaries have been trashed by nutrient over loading to the point that the US now imports 80% of its seafood."[2] At the same time, there is am ever-increasing demand for animal derived protein from developing countries, like India and China. However, in the future, land use for meat production will likely compete with land use for crops to feed a rising global population. Therefore, questions of how to reform the meat industry are abound, and VFs could offer at least a partial solution.

Despommier has asserted that, "fish and poultry could also be raised (in a VF)" (Despommier, 2009), though most of the literature on meat production in a VF to-date is incredibly vague. However, biologists like Dr. Martin Schreibman are working on creating an "enclosed system of fish farming, which could serve as a model for urban aquaculture in the future" (Gopnik, 2007). In a recent article in *The New Yorker*, Dr. Schreibman explained that:

> "'the demand for sustainable protein is *the* demand of this century…Somehow we're going to have to produce enough protein to feed our population, and we'll have to do it in urban locales, because the costs of transportation are going to become prohibitive'" (Gopnik, 2007).

[2] Taken from my interview with Despommier.

While raising smaller creatures in VFs, like chickens, ducks, turkeys, fish, shrimp, and mollusks seems feasible, protein from larger animals like cows or pigs is more problematic. However, with regard to this problem, some literature points to an altogether different approach to meat production in the future: I*n-vitro meat*, also known as *synthetic meat*. James Lovelock wrote in his most recent book The Vanishing Face of Gaia,

> "My dream is that we will discover how to synthesize all food we need from carbon, nitrogen, water, and a few minerals…" (Lovelock, 2009: 87).

Synthetic meat is already being developed in labs around the world. As A. McIlroy reported in a 2006 article titled "*Will Consumers Have a Beef With Test-Tube Meat*?" from Canada's *Globe & Mail*, that scientists have already "grown mouse and frog meat in the lab, and are now working on pork, beef, and chicken. Much of the muscle fibers grown in the Petri dish come from stem cells" (McIlroy: 2006).

II. VFs and Future Cities:

As if global warming, water shortages, and rapid population growth were not enough problems, it is also projected by the year 2050, 80% of the world's population will be based out of cities:

> "Every week, there are 1.3 million new people in cities. That's 70 million a year, decade after decade. It's the largest movement of people in history" (Brand, 2009: 26).

Thus, "now and in the future will belong to *Homo Urbanus:* The city-dweller" (Crane and Kinzig, 2005). In the LSE public lecture "*Cities, Design, and Climate Change*" (November 29, 2009) Saskia Sasseen pointed out that, "Cities demand resources (and this) generates a geography of extraction and process that span the globe." The current scale of food production and distribution is

really quite astounding when one considers that, "Every day, in the city of London 30 million meals must be produced, imported, sold, cooked, eaten, disposed of again, and something similar must happen every day for every city on earth" (Steel, 2008: ix). Obviously, the combination of population growth and urban expansion coupled with decreased fresh water supply and insufficient arable land could spell catastrophe.

Paradoxically, urbanization can have environmental benefits since cities are more land use efficient per person and "concentrate half the world's population on about 2% of the Earth's land surface" (Crane and Kinzig, 2005: 1225). In Whole Earth Discipline (2009) Steven Brand states,

> "Environmentalists have yet to seize the enormous opportunity offered by urbanization. Two major campaigns should be mounted – one to protect the newly emptied countryside, the other to Green the hell out of the growing cities" (Brand, 2009: 69).

VFs would be central to these green cities and could either share or dominate food production for the growing population. When Despommier discussed the possibilities of VFs, his enthusiasm was palpable. His vision is not only of a skyscraper farm, but also of an entirely new kind of city that is a large eco-system producing its own energy and with zero-waste:

> "Obama's job is to create sustainable cities… and (VFs are) the basis of the eco-city. Without food there is no eco! … We are a user-upper, not a producer. We need to become producers and recyclers. I think once you do that, just through a Vertical Farm, the larger picture of the entire city (will change). It's a no brainer after that!"

Despommier has proposed, for example, that VFs use city waste water to fertilize crops and release clean water back into the city system. This technology is already available in what is called a *plasma-arc gasifier*. His research assistant, Cox, explained:

> "…waste water holds 700 billion giga-watts of energy per year, so you would

> somehow have to redo all the city parts to funnel it into the VFs… a plasma-arc gasifier, which is this cool technology… it takes waste and it zaps them with (pause) I don't know what it zaps them with (laughs) but then what you get out of it is all the elemental parts which can turn a turbine and generate electricity."

Furthermore, Despommier has proposed that VFs could collect trash from NYC's 28,000 restaurants and capture the methane released from the decaying trash to fuel itself (Encyclopedia of the Earth, 2009). Currently, city governments in the USA (including Seattle and San Francisco) are looking into new ways to deal with city waste because new landfill sites are harder to come by, "Food waste, which the E.P.A. says accounts for about 13 percent of total trash nationally — and much more when recyclables are factored out of the total — is viewed as the next big frontier" (Kaufman, 2009). Here, VFs also present a strategy to deal with city-waste problems, while also shifting cities into zero-waste practices. In our interview, Jake Cox repeated several times that the entire notion of waste is what has to be done away with:

> "Bio-mimicery is the word. If we can mimic eco systems there is no such word as waste …get rid of the term waste. It's gotta be circles."

Hence, VFs would mark the beginning of a new kind of city and even a new kind of philosophy about human constructs and their role/relationship to the environment around them. These buildings would be, "alive…like trees, participating productively in their surroundings" (McDonough, 2002). Insofar as buildings would be alive, they would also be designed and constructed in accordance with the area in which they are built. So, for example, energy technologies used in Manhattan would be different then in Abu Dhabi based on heat, water availability, etc. Despommier explained in a recent article in *Scientific American*,

> "Location is everything… Vertical Farms in Iceland, Italy, and New Zealand, south California, and some part of East Africa would take advantage of abundant geothermal energy. Sun filled desert environments (ex. Middle East…) would actually use two or three story structures, but perhaps 50 to 100 yards wide but

> miles long, to maximize natural sunlight for growing and photovoltaics for power. Regions gifted with steady winds… could capture that energy" (Despommier, 2009: 87).

Thus, VFs have emerged as a correlate to the idea of building cities that are no longer " 'a human operation directed against nature'" (McDonough, 2002) but rather are focused on creating buildings that are part of a wider ecosystem, using already existing energy flows and even having a role in atmospheric regulation. VFs are part of a "new city (and a) new world, directed by a new kind of science" (Williams, 1993: 275).

III. Gaia Theory and VFs

The "new science" that is emerging is best encapsulated in the Gaia Theory (GT), originally proposed by James Lovelock in the 1970's. Lovelock's theory was once lambasted, but is now increasingly accepted, and can be summed up as the Earth (i.e. Gaia) is itself a living, life sustaining, and "self regulating system."[3] Much of the discussion surrounding Vertical Farming and sustainability in general has GT at the heart of it, though not always explicitly stated. Critically, GT has already had the affect of changing the way humans perceive their role and relationship to the world around them. In the case of future/sustainable cities, GT has been part of a dream civilization that would operate in a completely new way (zero-waste, low energy, bio-mimickery, etc.). These cities would also exist on a time scale that is relevant to the humans living within them, but not necessarily to the nature that surrounds them. For example, in a VF, crop yields would grow 4-6 times faster than outdoor acreage and would be grown year round. In this way, VFs can be seen as a technology that "seek(s) to humanize nature by appropriating it to human needs and concerns" (Picon, 1996: 40).

[3] Taken from CBC radio interview with James Lovelock, recorded January 2, 2008.

Hence, moving food production into the center of cities would mean that, "whole swaths of land could be returned to Gaia" (Lovelock, 2009: 87). In theory, the land would be able to restore itself through planetary processes that take decades, if not hundred (even thousands) of years[4]. Or as Despommier puts it, the countryside would be returned to nature "to rebound from our insults" (Despommier, 2009: 84). This is not a lack of vision Despommier's part, but by design: The countryside either becomes completely abandoned to restore itself, and/or it would become a kind of newly managed environment, where farmers would "get paid to sequester carbon" (Despommier, 2009: 84) through growth/management of forests and grasslands.[5] Many reports, including from the UN, have said that this is the fastest way to slow global warming. In our interview, Cox explained that:

> "We looked at the numbers and if the states of Illinois, Iowa, Kentucky, and Indiana stopped farming and just let the land go, in 20 years once hardwood forests starting showing up, it would be sequestering 10% of all the US annual emissions."

Research done in the UK by Gil Doron comes to similar conclusions. He reported that, "if all the food in the UK were produced organically and consumed locally…carbon dioxide emissions would be reduced by 22%. This

[4] It is important to note here, that should this become a reality it would essentially split the planet into two different temporalities: The time scale of "human nature" which is directly correlated to human needs (briefly discussed above), and "wild nature" which functions on a completely different time scale (i.e. centuries or millennia, versus decades).

[5] This also presents an opportunity for the US to institute a conservation strategy that would be closely aligned with complex negotiations being undertaken at the UN Climate Conferences. For example, currently at the UN global climate conferences, less developed countries (LDC) with forests (Brazil, Philippines, etc.) are under pressure to institute some sort of conservation strategy for their wilderness under the UN collaborative program (between the FAO, UNDP, and UNEP) for Reducing Emissions from Deforestation and Forest Degradation (REDD). Meanwhile, LDC are reluctant to commit to these strategies because they say they have the right to use their forests and land as tools for economic development and REDD interferes with principles of national sovereignty. Should VFs become a reality for countries around the world, not only would conservation become a part of everyone's agenda, but also "selective logging would be the norm for an enormous lumber industry…" (Despommier, 2009: 84).

reduction is twice the amount that the UK has committed to under the Kyoto Protocol" (Doron, 2005: 53). Here, it becomes clear what a huge environmental impact VFs could have since there would be no longer any need for heavy agricultural machinery, petro-fertilizers, complex methods of food distribution, etc.

Despommier has also predicted that less traditional farms does not necessarily mean less farmers. This is because, "large-scale urban agriculture with be more labor intensive then is currently practiced on the traditional farm scene…hence, employment opportunities are abound at many levels" (Encyclopedia of the Earth: 2008). In our interview, Despommier told me about a project he has just started with the city of Newark (New Jersey). The mayor of Newark has expressed interest in building the nation's first VF as a symbol of hope for a community that has experienced many difficulties in the past few years, especially at the level of poverty, crime, and gang violence. Despommier told me, "I want the ex-cons…those are the people that I want to work in the VF. I want them to work in the nursery, I want them to work in the harvesting, I want them to work in the waste energy. I want to, not rehabilitate these people, but give them purpose. Their purpose will be to feed the rest of Newark!"

In sum, VFs are being received and discussed as a strategy to deal with many complex, overwhelming, and seemingly unstoppable issues that are on the horizon. As the current methods of food production and distribution are being linked to disparate, problematic areas, it seems logical to deduce that if we reform our food production and distribution system, many of these problems will simply disappear. As Carolyn Steel wrote in her book Hungry City: How Food Shapes Our Lives,

> "Urbanism, capitalism, geopolitics, peak oil, hunger, global warming – faced with a list like that, where on earth does one start? It might strike us that there is something that does connect them all, not in an all-encompassing,

> *Gesamtkunstwek* sort of way, but in a complex, messy one. That something is food… Food, the ubiquitous medium of civilization, has always shaped the world..." (Steel, 2008: 307).

While reformation of local and global food systems would certainly have profound impacts, it is also important to note that within these discussions of the possibilities there is an Edenic or idealized narrative. VFs take on meanings as a panacea from everything globalization to population growth to global warming and food security, and even to health problems. In the recent Op-Ed NYTimes piece mentioned above, Despommier goes so far to suggest that the constant flow of fresh vegetables and fruits will "combat health problems, like Type II Diabetes and obesity" (Despommier: 2009). In another article, Despommier argues that the production of food in the center of cities is depicted as absolving us from ignorance about industrial food processes and "allow(ing) us to address in one ambitious but realistic strategy, the precarious and tricky crisis of modernity between the individual and the City" (Despommier & Ellingsen, 2008: 27). Vertical Farming, therefore, is depicted something that is "too good to be true" but also "realistic and achievable" **(**Encyclopedia of the Earth: 2008).

IV. VFs, Biotechnology, Biological Control, and Nature

The first VFs will be the equivalent of giant Petri dishes for human technological control. However, VFs are not just a new technology for food production, but also signify an emerging "style of thought" (Rose, 2003: 16-17) that focuses the scale of biological control on the most essential component of all human existence: Food. Like other biotechnologies, VFs are a "hybrid assemblage of knowledges, instruments…buildings and spaces, underpinned by certain presuppositions and assumptions" (Rose, 2003: 16-17). The presuppositions and assumptions in this case would be all the cataclysmic projections about global warming, population growth, etc. that have fully yet to

materialize. Any "solution" or strategy to deal with climate change or even projections about its effects, actually take place in an imagined set of futures based on inaccurate models. Even the GISS computer models that provide the data for the UN IPCC are reductive (see *Appendix B*). Put plainly, VFs have been conceived in the context of imagined futures, with imagined people, demands, capabilities, and limitations. Hence, VFs are not just a "technological artifact (or) technological achievement" but are objects that are "embedded with societal, political, and economic considerations" (Pinch, 1996: 23).

Since the 1970's, the environmental movement has "'morphed steadily into the climate change movement.' This means that Greens are no longer strictly defenders of natural systems against the incursion of civilization; now they are defenders of civilization as well" (Brand, 2009:1). With all of the projected environmental crises in mind, two credible and competing branches of scientific philosophy are emerging. On the one hand, there are those who argue that global warming needs to be tackled with a series of geo-engineering techniques. This would include, for example, "a fleet of fiber glass boats equipped with machines that would increase the cloud cover over the oceans" or the construction of "a vast network of tubes for sucking cold water from the depths of the sea to the surface"… and even "mimicking volcanoes" (Kolbert, 2009). On the other hand, is what Stewart Brand calls "*Eco-Pragmatism*" - an emerging environmental philosophy that seeks to balance the demands of civilization with those of the planet at large, recognizes the limits of human understanding and biological control, while also embracing technologies that might have previously been considered controversial by environmental activists. While either approach differ in scale and approach, it should be noted that in both cases "biology is no longer blind destiny, or even foreseen but implacable fate. It is knowable, mutable, eminently manipulable" (Rose and Novas, 2003: 5).

Eco-Pragmatism is a new approach to environmental conservation because it is an,

> "…environmental ethic that will teach us about using nature just as much as not using it. (The) wilderness dualism tends to cast any use as ab-use, and thereby denies a middle ground in which responsible use and non-use might attain some kind of balanced, sustained relationship" (Cronon, 1995: 85).

Critically, what is unique about Eco-Pragmatism it that it is an amalgamation of different philosophical branches about climate change, the role of technology, and the place/role of humans in the world. VFs fit well into Eco-Pragmatism and would even physically embody a changing relationship between humans and the planet at large. VFs would also create a whole new type and scale of "managed-nature" and even create new types of "natural."

Here it is important to point out that the objections that were raised when GMO's were brought onto the market are not at all present in any of the discussions about VFs. But, one has to wonder how VF crops are any more "natural" than GM foods? For example, if an organic almond plant seedling is planted in vermiculite in a VF, pollinated by the hand of a human being, and given the exact amount of sun/artificial light to grow to its fullest potential, do that make the resulting almond "natural"? In my interview with Cox, I asked him "Which is more natural – GMO's or VFs?" To which he replied:

> "Does what humans do count as natural unequivocally, or are some things natural and some things unnatural? iPods are probably unnatural, but… organic shoelaces are somehow more natural. (Despommier) always says farming is the most unnatural thing we do…I don't think VFs are any less natural…if any thing they are more natural because they are taking a holistic approach to the human place in the world. You are giving farmland back to nature."

Hence, VFs are considered more "natural" because they were conceived of with a holistic vision in mind; and because VFs are a part of a more holistic philosophy, they are also considered more "natural" and therefore this solution is being embraced without calls for the precautionary principle, as occurred

when GMO's emerged. However, in reality the long-term affects of sealing off food from the outside world are simply not known (discussed further below).

Certainly, should the aforementioned complex and interdependent global problems (such as environmental degradation, water shortages, population growth, urbanism, etc) become a reality, a new way of thinking and managing both humanity and the planet itself will be required. In order to cope with the complex set of issues facing humanity and civilization in the future, disparate branches of knowledge and science must somehow come together to accommodate the needs of a new kind of global society and even a new kind of planet. Fundamentally, what will have to change is the propensity to think in disciples that are "each capable of operating in their own vacuum" (Steele, 2008: 305). As Wendell Berry explained in a recent CBC radio interview, the tendency towards specialization has broken down science into small, more manageable parts, but "there is such a thing as too much specialization… (And) it can become deadly if carried too far."[6] As mentioned previously, Gaia Theory, once mocked, is now gaining more attention and credibility in scientific circles as studies in ecology, biology, chemistry, physics, and climatology reveal the interrelated nature of all planetary systems and all life on Earth, as well as the dependence of humans and civilization on planetary stability:

> "' There tends to be very little, if any treatment of the roles played by climate change, deforestation, soil fertility, and plants and animals in the past. How (people) went about feeding themselves and treated human and animal waste barely rates a mention, and yet it remains one of the fundamental aspects of human existence" (Ted Steinberg quote in Foltz, 2003: 20).

While researching, this final point became abundantly clear. History and current issues are not discussed in terms of the environment, unless the analysis is explicitly tailored from this point of view. However, as the population

[6] Taken from CBC's radio series "*How to Think About Science"* Berry interview aired January 16, 2008.

continues to grow and resources become slim, an understanding of human dependence on natural systems will become alarmingly clear. Hence, "climate change may well turn out to be *the* historical event of our times, which future historians may see as the matrix within which all other historical events of our era unfold" (Foltz, 2003: 20). VFs would in part be the physical embodiment of a new philosophy about humans' role/relationship to the planet at large, but also signify a new relationship between disparate branches of science. For example, the R&D necessary to build and sustain VFs include areas like, "hydrobiology, engineering, industrial microbiology, plant and animal genetics, architecture and design, public health, waste management, physics, and urban planning, to name a few" (Encyclopedia of the Earth: 2009). Hence, VFs would integrate complex and disparate sciences to focus the scale of biological control, while also creating new human/nature hybrids.

At the same time, it must be highlighted that the very idea of Vertical Farming stands as a testament of the tendency towards the techno-scientific control and solutions in an increasingly scientific and technology dependent world. As Adele Clake wrote in her book Disciplining Reproduction, "The biomedicalization of life itself (human, plant, and animal) is the key overarching and usually taken for granted *social* process here" (Clarke, 1998: 275). So while Vertical Farming is an absolutely unique idea that aims to be a holistic strategy, it remains a techno-scientific solution to a series of social/cultural problems. For example, VFs do not address population growth, they just provide a solution to feed billions more people. In this way, VFs feed into Jasanoff's (1996) *myth of sustainability* which, "signals the possibility of overcoming resource limitations through human enterprise" and the "indefinite survival of the human species (…) through a marriage between scientific knowledge and rational stewardship" (Jasanoff, 1996: 186). Furthermore, VFs do not address some fundamental social and economic problems, because "even if the wishful thought that biotechnology could increase food production…became a reality, that is not the same thing as

providing people with food. There remain certain underlying issues of poverty, food distribution, and economic and social policies" (Holdrege & Talbott, 2008: 30). However, while one could reasonably argue that VFs do "substitute a technological order…with scientists 'at the helm'" (Clarke, 1998: 249), they could also be a solution to a series of problems that would otherwise require global political coordination, increase agro-chemical farming techniques, and controversial interventions into the private lives to stop or limit population growth.

V. Limits of the VF vision

Problematic dichotomies

The idea that land will simply restore itself rests on the assumption that humans have not already damaged land beyond repair. As Al Gore pointed out in his documentary *An Inconvenient Truth*, "Our new technologies, combined with our numbers, have made us, collectively, a force of nature." Entire areas of forest have been eradicated, minerals extracted, top soil depleted, swamps filled to accommodate the rising demands for resources, chemicals and toxins introduced, etc. Furthermore, different species of planet, bug, fish, and animal have been traded, transported and invaded new eco-systems over the centuries, often with devastating effects. In short, humans have already altered almost every corner of the planet, including "'every cubic centimeter of the biosphere'" (Low, 2002: 46).

Therefore, the concept of "wilderness" as standing *apart* from civilization is in fact a cultural construct that the environmental movement has relied on for some time, but is extremely problematic. This is because Civilization/Wilderness dichotomy,

> "embodies a dualistic vision in which the human is entirely outside the natural…(and therefore the problem with) wilderness is that it quietly expresses and reproduces the very values its devotees seek to reject…It represents a false hope of an escape from responsibility, the illusion that we can somehow wipe clean the slate of our past and return to the tabula rasa that supposedly existed before we began to leave our marks on the world" (Cronon: 1995).

The Civilization/Wilderness dichotomy also carries the implication that "the transformation of nature through biotechnology" (Merchant, 1995: 153) will save civilization and ensure human survival. However, this fails to address the fundamental ideological/philosophical problems that have led the planet to the precipice of this environmental crisis in the first place. As Lynn White wrote in his seminal essay *The Historical Roots of Our Ecological Crisis*, "What we do about ecology depends on our ideas of the man-nature relationship. More science and more technology are not going to get us out of this present ecological crisis until we find a new religion, or rethink our old one" (White: 1967).

The extent to which VFs would constitute a re-thinking of our "old religion" is complicated. On the one hand, VFs are clearly an attempt at holistic thinking and would be part of a city that has an entirely new relationship to the planet. On the other, it is also possible that VFs could make us feel isolated from the 'wild' natural world. Humans might experience complete control over food production as a move away from nature, as a sequestering and/or a transcendence over the natural world, as opposed to a part of it. In other words, VFs could re-create the current human relationship to the planet, which is proving incredibly problematic, damaging, and even dangerous. As James Lovelock points out in his most recent book The Vanishing Face of Gaia, "we lost contact with the Earth when our food and sustenance was no longer immediately dependant on the weather" (Lovelock, 2009: 148). Hence, in the total control and manipulation of food production and nature for our own survival we could lose the appreciation of the "dynamic, autonomous role of feature and phenomena

(which) promotes the illusion that humans can construct and control everything" (Spirn, 1995: 112).

Using Latour's ANT to consider some long term problems:

While VFs are an attempt to think holistically about the set of complex problems discussed above (population growth, urbanism, environmental degradation, etc.) it still fails to look at other types of "living' things as actors in the network, specifically the plants themselves. Latour's Actor Network Theory (ANT) is based on the idea that non-human elements have agency to the same extent that humans do. This is helpful in analyzing VFs because it illuminates the possibility that "no science of the social can even begin if the question of who and what participates in the action is not first of all thoroughly explored, even though it might mean letting in elements in which, for lack of a better term, we would call 'non humans'" (Latour, 2005: 72). In the case of VFs, one has to look closely at the role of plants and their interactions with external factors (soil, weather, pests, viruses) that have shaped what they are.

The sequencing of the human genome in 2003 led to the surprising discovery that pests, disease, and/or viruses have had an evolutionary role. What was once referred to as 'junk DNA' has in fact been discovered as, "shards of retroviruses… that 'helped make us who we are today just surely as other genes did' (Specter, quoting Dr. Thierry Heidmann, 2008: 276-277). Hence, viruses "represent a 'major creative force' in our evolution, "driving each infected cell to acquire new and increasingly complex molecular identities" (Specter, 2008: 291). As Robin Weiss, professor of Oncology at University College of London, pointed out "'if Charles Darwin reappeared today, he might be surprised to learn that humans are descended from viruses as well as from apes" (Specter, 2008: 279). This leads to inevitable question: Do we really understand enough about evolution/nature/biology to assume control?

A recent NYTimes article titled *Sorry Vegans, Brussel Sprouts Like to Live Too* (December 22, 2009) recounts the many ways that scientists have been astounded by the "complexity of plants" (Angier: 2009). It goes onto chart Dr. Monica Hilker's work at the Institute of Biology at the Free University of Berlin and the variety of ways that plants, "respond to tactile cues…recognize different wavelengths of light, and even 'talk' to each other" (Angier: 2009). Crucially, the growth, development, and life of a plant are directly tied to its healthfulness when consumed by humans, because,

> "…flavanoids are phenolic compounds that have potent antioxidant activity (and are) produced in plants in response to environmental stressors, such as insects or competing plants...(so) by protecting the produce from these pests, we decrease their need to produce antioxidants (which) suggests that maybe we are doing something to our food inadvertently."(Bryum quoting Dr. Alyson Mitchell: 2003).

The question raised, therefore, is would VF make plants so "hygienic" they would become less healthy for humans to consume? When I asked Despommier about this during our interview, he seemed taken aback and I got the distinct impression that it was not something he had yet considered. He responded:

> It's a good question. What are the effects of hermetically sealing off a plant to its future evolution? Does the plant become less resistant to natural forces because you have protected it and coddled it? And what about us? Has that happened to us, since we have learned to live inside of buildings for instance?... Will similar things happen to plants? Do we have examples of plants we can show changes in? We have not been doing research that long to know the answer.

Again, here the question arises why VFs have not received the same precautionary stance as GMO's? Before total biological control of the food supply, wouldn't it be wise to investigate the effects of growing plants in sterile conditions to protect us from creating new problems with our supposed solution?

Furthermore, one has to question whether/how the operation of VFs will change the human relationship to plants through constant management and manipulation. Twice in our interview, Despommier alluded that VFs would change the relationship between plants and humans in a completely controlled environment. He postulated that keeping honeybees in the first VF would be a problem due to current technical constraints, but "we also have lots of people, so each person could be a worker bee…" Furthermore, he noted because the crops in a VF would be completely biologically controlled, "you could stress a plant and make it produce the reproductive organ of your choice, namely the grain of your choice." However, what must be recognized is the fact that, "the skills enabling us to manipulate a thing are not necessarily the skills in yielding a deep insight into its nature" (Holdrege & Talbott, 2008: 170). This notion must be firmly kept in place, so that knowledge about plants grown and developed inside a VF are not then applied to plants in the 'wild' or in Nature. There is a distinct risk that humans could attempt to manage nature on the outside with the same methods and knowledge acquired from managing plants on the inside.

Funding:

The biggest problem for VFs right now is funding, which in Western liberal democracies also involves questions of ownership. One has to wonder whether VFs would be publicly owned, or whether large agri-business would come in to build and operate them. In the recent *Scientific American*, Despommier wrote about the funding and development of VFs saying, "University partnerships with companies such as Cargill, Monsanto, Archer Daniels Midland, and IBM could fill the bill" (Despommier, 2009: 84). However, should Monsanto, Cargill, and other large food companies operate and own VFs, then how is that different than what is happening in the farming policy today, albeit under totally different surroundings? The disconnection here is that "research in agriculture…(focuses) on the pursuit of profit-maximizing (…) in a context of

thoroughly protectable property rights on innovation" (Scandizzo: 2009). However, Despommier envisions VFs as the anti-thesis to all of this. In most of Despommier's articles, VFs are meant to connect people to their food and act as a strategy by which the industrial processes behind food previously, "made invisible, unquestioned, (and) absolved by sheer ignorance" (Despommier and Ellingsen, 2008) are exposed for all to see.

Fundamentally, putting VFs in the hands of agri-business would once again pull food choices out of the hands of consumers and into the hands of the corporate world, whose main objective is the bottom line. Furthermore, since biological innovation creates *bio-value* and potential for profit, VFs have the potential to "(generate) new objects of contestation, not least of those concerning the respective powers of public bodies (and) private corporations" (Rose and Novas, 2003: 7). Already, the combination of private business aims, intellectual property, food, health, and profits has created "novel forums for political debate (and) new questions for democracy and styles of activism" (Rose and Novas: 2003, 7). If VFs are introduced and are completely operated by big business, these issues will inevitably re-emerge, not simply disappear.

In my interview with Jake Cox, I asked him "Who would 'own' VFs?" To which he replied:

> "I really don't think (Despommier) thinks that Monsanto and DuPont should get behind these things….We both think that if the funding comes from some public source, or some international organization (UN, or FAO)… But how do you do that? How do you get public money to pay for something unproven? How do you get people to stay with it through all the mistakes?... This could do so much good there. It does not have to be profit generating…But then again, capital-capital-ism. You can't do anything unless it's profitable… how much good could you do if there was a business whose model was unprofitable?

Technological Barriers:

Technologically speaking, there are still barriers to constructing VFs, mostly in how to integrate all the engineering systems. During our interview, Despommier explained:

> "Herbert Einstein at MIT (is looking) at engineering issues to be dealt with… These guys tell me that the only difficulty of doing this would be to work out (pause) It's the same problem that engineers had when they went from a one-stage rocket to a two-stage rocket, or from a two stage to a three stage. It requires integrating all the systems… this building needs to guard against infections, insect pests… it needs to recycle all the water from harvesting, but also from the humidified atmosphere."

Also, before VFs could become a reality new, reliable sources of energy and electricity would have to be perfected. As many New Yorkers were reminded in the blackouts of 1977 and 2003, "city dwellers" are totally dependant "on a constant, unvarying supply of electricity. Without it a city dies, and quickly as you would without oxygen" (Lovelock, 2009: 88). In theory, VFs would be completely powered by a series of new alternative energy sources including solar and wind. However, these technologies, while increasingly popular, also will have to be further developed before they become reliable sources of energy.

VI. Discussion of social, cultural, and political resources necessary for VF to become visible

I have argued that VFs represent a new "style of thought" (Rose, 2003: 16-17) and a new philosophy about the scale of biological control. But also, the very *idea* for VFs has come about in a moment when, "the average person's interest in (food) is increasing…(and) awareness about global sustainability and the interconnectedness between our cities, food sheds, regions, countries, and

continents is also growing" (Peters, et al. 2009: 79). This increased awareness of the impact of food production has begun to spawn news kinds of markets, and even more significantly, new types of consumers. The "conscious consumer" is aware, highly educated, thoughtful, less wasteful, and are even considered "global citizens." VFs speak to all of these modern day virtues, while also providing a glimpse of what the future of civilization would look like. But before VFs can become a reality, a new type of "green citizen" will have to emerge due to external and internal stimuli.

Changes in peoples' attitude towards food are already occurring and will undoubtedly have a profound impact on the future of food production, distribution, and consumption. In a *National Public Radio* interview to discuss his most recent book titled Eating Animals, Jonathan Safran Foer explained that food awareness has already a tremendous effect on the cultural/social level, with more to come:

> "18% of college students now describe themselves as vegetarian. There are more vegetarians than Catholics in American universities. There are more vegetarians than any (college) major, other than business…and when those 18%(...) become culture makers, 5 years from now, I think the conversation is going to feel quite different" ("On Point" NPR interview, 2009).

Hence, VFs will not just be imposed or adopted from the top-down, but also will emerge from the bottom up. As the planet gets warmer and more crowded, individuals and society will surely adapt and change. As Latour has written, "for each state of Nature there exists a corresponding state of society" (Latour, 1993: 95). Among the changes will be modifications in "law (and) established customs" which is both aided by and supports "social transformation" (Latour, 2005: 73). Certain "push factors" like droughts (Encyclopedia of the Earth: 2008), or increasing storms, damaged crops, falling profitability could form a new type of "green citizenship" that will not only appreciate and understand civilization's reliance on a stable climate and reliable water supply, but also will be able to think in an entirely new way. The new

dynamics of a warmer and more crowded planet will also form a new global society that will create new "obligations, and (…) forms of biosociality with which they are linked (that are) specific to certain times and spaces…Aspects of citizenship are constantly reshaped in relation to new causes are often inventive in their styles or organizing and activism" (Rose and Novas, 2003: 22, 24). Furthermore, the daunting problems we face in the future will require us to think less in terms of immediate pay offs and reflect more on long-term strategies for survival. Inevitably, we will also have to adapt to a new way of thinking that is more holistic and abstract, rather than linear and specialized. Hence, as these changes come to fruition, political, economic, cultural, and social institutions will inevitably have to adapt to the new environmental limitations and new consumer needs and demands.

Cultural change "on the ground", so to speak, will inevitably have an impact on political and economic circles as well, though at present VFs still have many obstacles to overcome in these areas. On a phone interview I had with John Fisher, founder of *Draper Fisher Jurvetson* - a hugely influential global venture capital firm currently making investments in alternative and green technologies- he expressed doubt over the potential for VFs to really take off due to limitations of current city policies & zoning, real estate/land availability, etc. He noted as of today, VFs "are not appropriate for Venture Capital community… and if (ideas) do not make economic sense, then will not happen."

However, investors/venture capitalists might change their mind if the supply /demand balance shifts in the favor of VFs. If all the discussed projections are correct, the planet stands to undergo many (possibly quite dramatic) changes over the 50-100 years. As explained previously, "demographers project that the world's population (will rise) from six billion to nine billion by 2050--almost entirely through a net addition to urban populations--the planet will need to cultivate a billion more hectares of arable

land…researchers say that much arable land simply doesn't exist" (Fischetti, 2008). Changes in the climate are already having an impact on food production around the world, even in places like Italy and France where recent summer heat waves have negatively impacted crop yields by 36% and 30% respectively (Walsh: 2009). Late 2009, *The Economist* reported that seasonal planting in areas of East Africa has become increasingly "'useless'" as "moderate, temperate seasons are shrinking (and) rainy seasons are shorter and more violent" (Economist quoting Oxfam's John Magrath, 2009). If these climate trends continue, "researchers estimate that half the world's population could face a climate-induced food crisis by 2100….With these frightening prospects in mind, we need to try to heat-proof our agriculture" (Walsh, 2009). Therefore, VFs could even prove one day to be *more* reliable investment in agriculture as, "crop production is not limited by seasons or adverse weather events (and) sales could be made in advance because crop-production levels could be guaranteed" (Despommier, 2009).

However, as of now, there remains a "complex web of regulations and laws…including policies set by city departments for land use, water, waste, engineering, and planning" (Peters et al, 2009: 30) in place that make VFs a political and economic impossibility. Ultimately, until the environment itself becomes a precious resource it will not be priced and therefore it will not hold monetary value. Still, marrying economics and ecology is complicated because it requires us to "price" natural flows with a conventional understanding of the market.[7] Thus, the connections between the stability (even survival) of civilization upon things like water, stable climate, weather, etc. need to become more apparent before any changes or adaptation of political, economic, social, and cultural institutions take place. Hence, chances are that VFs will not emerge on the city horizon within the next fifty years or so.

[7] Information taken from LSE public lecture with Saseen (November 29, 2009).

However, there is the possibility that VFs could sooner emerge to *share* the burden of production. In our interview, Despommier suggested that VFs could initially be used as huge green houses for switch grass for biofuels/biodiesel. These types of carbon-neutral fuel potentially hold great environmental benefits, but remain controversial because "environmentalists say that if the use of biofuels is promoted, than more and more land will be used to produce crops to make biofuels. This will result in a loss of habitat for various species of animals and plants… (as well as) a reduced food production can increase the prices and cause the inflation to rise" (Rutherford: 2009). Also, during our interview, Despommier explained that:

> "the French cultural society (was) meeting in Paris and they (found) out that I (was) in town and they (asked me to) give them a lecture on (VF). And I was thinking 'Are you kidding? French are so attached to their cuisines that they would never even think about growing food indoors. Wanna bet? They know the climate is changing, they know the grape regions are changing. They can sense this now and they don't know what to do…"

These are two examples where small-scale VFs could be mounted as experimental procedures that would also have real economic benefits should the technology prove successful. Furthermore, as mentioned above, cities are already struggling to find a solution to their waste management problems, and VFs could aid in this area as well. As of now, real estate in cities would be too expensive for farming, but Despommier has said that VFs do not just have to be "big towers…. You can do this on the rooftops of hospitals and schools…You can do this along the periphery but still within city limits. You can do this on open stretches of air force bases and airports and city islands" (Fischetti, 2008). Hence, VFs can be seen as the apex of an urban agricultural movement, which is already in effect, though still in its infancy.

VII. Conclusion:

In this essay, I have attempted to provide a thorough summary of Vertical Farming as a biotechnology that would bring food production and distribution into the center of big cities. As explained, VFs would protect crops from encroaching parasites, bugs, and pests that can jeopardize food supply, and in the face of complex problems such as population growth, insufficient arable land, foot shortages, climate change, and urban crowding, VFs provide a solution for guaranteed food supply and protection. While VFs are a difficult idea to critique, especially in light of all the aforementioned crises, I have also attempted to provide an analysis of areas where the idealized narrative could over look some fundamental problems including, most critically, risking the health of the plants being grown within VFs.

Beyond the fascinating technical aspect of VFs, I have also attempted to outline a new and emerging philosophy, which includes a focused scale of biological control. VFs represent an appealing solution the aforementioned intertwining crises because it stops short of complete planetary control (ie geo-engineering) and instead focuses biological control onto civilization, while leaving the rest of the planet to restore itself. In addition, I have also aimed to outline the way in which VFs mark the beginning of a new kind of building, and also a new kind of urban ecology. As discussed, the designs for VFs include eco-friendly architecture strategies that employ bio-mimicry technologies, zero-waste principles, and techniques for energy consumption and renewal. Therefore, the visions of VFs and the cities of which they would be a part is a new and distinctive global society, based mostly out of sustainable cities. These cities would emerge out of necessity, as a variety of inescapable factors begin to

collide. In my discussion of the social, cultural, economic, and political changes that would need to take place for VFs to become a reality, I have aimed to show how VFs are not just a technology, but part of a social and cultural process that will force humans to rethink their role and place within the wider Life sustaining system that is Earth.

Appendix A:

Hydroponics:

A basic definition of hydroponics is the growing of plants without soil. Instead, plants are grown in mediums (including Rockwool, Geolite, DFT Irrigation) to provide the root structure with support so that the growing plants will not collapse (more information on mediums can be found at (http://www.thefarm.org/charities/i4at/surv/hydro.htm). There are several different kinds of hydroponic systems, including *Ebb and Flow Systems*, *Nutrient Film Technique, Drip Systems, Aeroponics*, and *Wick Systems* (more specific information on how each system works can be found at http://home.howstuffworks.com/hydroponics3.htm). Different types of hydroponic methods are suitable for different types of plants, depending mostly on height/weight of the plant. Once the root systems of the plant are grown into the medium, water and a combination of nutrients and minerals are run underneath so that the root system can absorb it. Because the combination of nutrients and minerals can be adjusted to the needs of each individual plant species, plants have a tendency to grow faster and with higher yields in hydroponic farms. Furthermore, plants grow faster because they concentrate their energy on producing plant mass, rather than roots as the mediums provide the stabalization.

Hydroponics has several other benefits including that it uses up to 70% less water and is also less space consuming because varietals can be grown on top of one another, and therefore closer together. Currently, one of the largest hydroponic farms in the world is at *Disney World's Epcot Center*. They have been

so successful at growing plants that the Epcot Farm provides the food for the many scientists that reside and study there. One of their tomato plants has produced over 32,194 fruit from the same plant in a period of one year, a world record (information taken from Discovery Documentaries "Disney Gardens Ditch Dirt" available at <http://dsc.discovery.com/videos/earth-disney-gardens-ditch-dirt.html>). Hydroponics also presents the possibility to grow food anywhere, including deserts or even one day, outer space. As Despommier has written in an article about VF, "(hyroponics) is being incorporated by NASA engineers into all future programs that focus on colonizing outer space… If we are to live in a balanced extraterrestrial environment, we must somehow learn how to do it here first" (Encyclopedia of the Earth: 2008).

However, hydroponics is not without its problems. To a certain extent, the systems are reductive as it reduces the "vast biological complexity of soil to NPK (which) represents the scientific method at its worst. Complex *qualities* reduced to simple *quantities*" (my emphasis, Pollan: 2006). Nutritional disorders of plants due to hydroponic techniques include "deficiencies of most of the essential nutrient elements – nitrogen, potassium, calcium, magnesium, sulfur, phosphorus, iron, manganese, boron, zinc, copper" (Munns, no date provided).

Appendix B:

GISS models:

In Elizabeth Kolbert's book Field Notes From a Catastrophe: A Front line Report on Climate Change (2007), she explains climate change modeling done for the IPCC as follows:

> "Like all climate models, GISS's divides the world into a series of boxes. Thirty-three hundred and twelve boxes cover the earth's surface, and this pattern is repeated twenty times moving up through the atmosphere… In the real world, of course, such a large area would have an incalculable number of features; in the world of the model, features such as lakes and forests, and indeed, whole mountain ranges are reduced to a limited set of properties, which are expressed as numerical approximations…Two types of equations that go into a climate model. The first group expresses fundamental physical principles…the second group describes- the term of art is 'parameterize'- patterns and interactions that have been observed in nature but may be only partly understood, or processes that occur on a small scale and have to be averaged our over huge spaces. All climate models treat the laws of physics in the same way, but, since they parameterize phenomena like cloud formation differently, they come up with different results. Also, because real world forces influencing the climate are so numerous, different models tend, like medical students, to specialize. GISS's model specializes in the behavior of the atmosphere; other models in the behavior of the oceans; and still others in the behavior of land surfaces and ice sheets" (Kolbert, 2007: 101, 103-104).

GISS models are also run backwards to see how accurate their approximations are. So for example, a computer model would run an equation that starts from the beginning of the industrial age to now to see if the results link up to real world observations. Ultimately, what should be taken from this is the fact that while climatology models are a complex science that attempts to combine and balance as many factors and equations as possible, the world on the computer screen is not as complex and interactive as the planet really is.

Appendix C:

Interview transcript (Despommier and Cox):

***Important note*:** *These interviews were held at Columbia University in Despommier's office. Several times, we were interrupted by phone calls/drop in students. Also, both Despommier and Cox had a tendency to go off on tangents. When I was transcribing and analyzing these interviews, I decided it was not helpful to include things said/discussed that did not pertain to VF. Times included are for my own reference, so that I could scan back to the appropriate place on my digital recorder to verify quotes.*

Q: What are some important connections between VFs and Molecular Parasitology?

A: … Great question… I began with an interest in biology… I had no interest in medicine… what I wanted to do was (pause) I loved telling stories that are true and I love teaching. The medical center gives purpose to my life and in addition, of course, lets me do research that has relevance to the future health of whoever. So I did biomedical research, which had a disease entity as its focus. And it worked on triganosis… (03:16)… Everything is connected, as you know, even economic theory…. The point is that I have always been interested in how diseases spread from person to person, so there is an ecology to this… and since this is a food borne illness… not all of them required by eating meat...many of them are acquired by food handlers that have the disease… (04:15)… *John Snowe Website* (water and cholera)… (06:26)… *Lost his grant, became a professor…Got a grant from Pfizer* "They were very generous in those days because of the Viagra revolution." … *Set up websites with the grant money and started teaching ecology and medical ecology course* (1999)… Students wanted to work on something with relevance to helping the environment (08:08)… So, they wanted to work on a roof top garden scheme to feed NYC. They asked, 'how many people could we feed

in NYC if we were grow food on roof tops?' It's a pretty simple concept, but they had to find out how many rooftops there were and how much acreage there was and what the crop was. It turned out the most energetic crop is rice and rice will feed 2% of the City population if you grow it on a non-commercial rooftop. They were even angrier, but with themselves, not me. I turned to them in a moment of frustration almost 'well, OK, there is a lot of abandoned houses and a lot of open lots. Food can be grown inside with hydroponics, lights, and stuff… and so, let's do that! Let's take this idea and expand the growing idea to include the inside of buildings as well as the outside. That's a hell of an idea! But, OK, class dismissed and that was the last class. But the next year (pause) well during that summer, I was driving to work with my wife… and we were talking…. And we were brainstorming though this and it seemed like a reasonable approach (09:50). Then, I started to amass all the reasons why it would be a good idea. Forget about the technical aspects and just say you can't do this, what are the advantages? First there is no agricultural run off…. (10:11) All of the estuaries have been trashed by nutrient over loading to the point that the US now imports 80% of its seafood (10:30) and agricultural run off is the world's biggest source of pollution, and it is totally unregulated. And with good reason!! How are you gonna regulate this? I see a front coming in right now and it looks like it is gonna rain. Can you say, 'Oh Jesus, well I would prefer if it did not rain.' (laughs) All of these things that are totally uncontrollable outdoors are totally controllable indoors. (11:15)… Again, an economic thing. If you look at FAO's biggest list of offenders as to why the farming operation of the world is failing it is because of agricultural run off, period. And the two reasons for it are wind and rain or flood erosion. Both of those things take topsoil and move it into the oceans, basically… Number 2 is there are no seasons! (12:20) Outdoor farmers are the most religious people you will ever want to meet… If you believe in God, I believe that God created the Universe and all the laws of Nature and these are part of that. So it is up to us to use our brains to figure out a way to have what we need without spoiling everything… Number 3 no adverse weather affects… Number 4 is that

we use 70% less water… So there are lots of economic reasons for doing this as well and one is that you get a tremendous yield in doors (14:31). Like for instance, 16 heads of lettuce per square foot per year for hydroponic farming… Lettuce economics (through 15:17). But the biggest reason, of course, has to be the repair of the environment.

Q: If you had $40 million in the bank tomorrow, what areas of VFs would need more work technologically speaking?

A: Herbert Einstein at MIT conference… (16:30) looked at engineering issues to be dealt with. Needed to look at "systems integration approach" … These guys tell me that the only difficulty of doing this would be to work out (pause) it's the same problem that engineers had when they went from a one stage rocket to a two stage rocket, or from a two stage to a three stage. It requires integrating all the systems… Well, this building needs to guard against infections, insect pests… it needs to recycle all the water from harvesting, but also from the humidified atmosphere and you can do this very easily… you have to keep the floors separated. You might also have issues of pollination… you will probably have to keep bees… (18:30)… but we also have lots of people, so each person could be a worker bee… Ummm. Electrical Systems and Energy Recycling…. (18:50)… So with $40 million, I could build you not only the most amazing prototype, but also hire the right people to work in it…As we speak, if you look just across that river, Newark…is on the verge of asking us to do this…As a result of that article I read in the NYTimes. That day I got a call from the White House (20:00), from this guy by the name of Alfonso Carrion, who used to be the borough president for the Bronx and he is now the Department of Urban Affairs Chairman of the Obama Administration. He called me immediately and said 'this is just exactly what we need to do. This is a long-term solution to this problem. We need to do it.' I told him 'What took you guys so long?' and he laughed. This is exactly what we need! This is a long-term solution! And the next

call I got was from the mayor's office in Newark… (21:00). *Seattle Architecture Firm: Weber Thompson eco-laboratory…* (21:50) You could actually make a building dedicated to making switch grass, which makes bio-diesel…Have a fundraiser dinner… (23:40)…You can't do (anything) before you allow the scientists their freedom to play inside of this thing and work it all out. And then you have to socially market which crops are you going to grow? Who needs to eat what? Who are you gonna feed? (27:35)…Despommier wants ex-cons to work in VF "Those are the people that I want to work in a VF. I want them to work in the nursery, I want them to work in the harvesting, I want them to work in the waste energy... I want to, not rehabilitate these people, but give them purpose. Their purpose will be to feed the rest of Newark! Obama's job is to create sustainable cities… so this is the basis of the eco-city (29:25)… Without food there is no eco! We are a user-upper, not a producer. We need to become producers and recyclers. I think once you do that, just through a VF, the larger picture of the entire city (will change). It's a no brainer after that! … France, SOA architect group…"The French cultural society is meeting in Paris and they find out that I am in town and they want me to go over and give them a lecture on this. And I think 'Are you kidding? French are so attached to their cuisines that they would never even think about growing food indoors. Wanna bet? They know the climate is changing, they know the grape regions are changing. They can sense this now and they don't know what to do…

Despommier left the interview to go to an appointment, and I resumed interview with his research assistant, Jake Cox.

Q: What are some important connections between VFs and city infrastructure?

A: It's all already been developed…The VF is the nexus of food, energy, and water problems… and it is It's a holistic approach to all these city planning issues that have been only been tackled one by one. So you are right: Waste water

would be… you know waste water holds 700 billion giga-watts of energy per year, so you would somehow have to redo all the city parts to funnel it into the VF's… a plasma-ark gasifier, which is this cool technology… it takes waste and it zaps them with… I don't know what it zaps them with (laughs) but then what you get out of it is all the elemental parts, which can turn a turbine and generate electricity… Unused or uneaten food from restaurants (40:00) …I mean what I am envisioning is some sort of delivery service which goes around to restaurants and homes to collect garbage and then takes it to a VF. I mean there is this greenhouse in Canada called Green Northern Hydroponics that uses a co-generation machine and it's a hydroponic greenhouse… what they end up doing is to sell back like 1200 watts for 20 years back to the city of Ontario. So it's a greenhouse that is fully functional… but they are actually making money by selling money by selling power back to the City. So from a business perspective this has already been done… One of the major questions against VF is about energy… (41:30)… VFs will be different depending on location… it would have to be completely carbon neutral and it would have to produce more energy then it makes…And there are ways to do that right now, and examples we can point to.

Q: What are some main objections of VFs?

A: Energy is the main objection. People also don't realize what kind of materials we would use to build it. People say concrete is very carbon intensive to produce. OK, let's not use concrete. It's not very green anyway…so from the get go, write off concrete, write off steel, and probably write off glass. You know the Eden project?... ETFE, it's 1% the weight of glass… It's like plastic… It's clear enough to do astronomy through… It's self cleaning…All UV rays get through… (Beijing water cube is made out of this)… This is what we both think that you would start making VF out of...It's a pillow construction (air between two layers) so it is strong….So objections are energy of concrete, energy of lighting…If you

are using all of the city's effluent… I mean if you are starting with the premise that you have to create more energy that you consume…I think it is possible. I mean, naysayers just doesn't seem constructive…One other concern that people raise is financing. It is more valuable to use housing to house people, not plants.

Q: Who "owns" VFs?

A: My opinion is what Dix's would be. I really don't think he thinks that Monsanto and DuPont should get behind these things. He realizes how much harm they have caused. We both think that if the funding comes from some public source, or some international organization (UN, or FAO)… But how do you do that? How do you get public money to pay for something unproven? How do you get people to stay with it through all the mistakes? This is a hard question. I think the Gates Foundation would be a great place to get money from… (ME: refugee camps)… (49:15)…I think there is a lot of promise putting VFs in places where people don't have food or don't have access to healthy food. So definitely, refugee camps, disaster areas… (50:30)… People who want to change the world should go see how the poorest people live… This could do so much good there. It does not have to be profit generating…But then again, capital- capitalism. You can't do anything unless it's profitable… how much good could you do if there was a business whose model was unprofitable?

(ME: I guess it changes the question what you consider profitable. Cause you are going to be feeding people and that is productive in another way.)

I have heard that argument that heard these arguments that healthier people are more economically valuable. So then you get the IMF to fund this… or the WB even. Healthy people are profitable: Some take home message that you can get people to rally around.

One of the obstacles is going to be getting the consumer to think that hydroponic foods are just as healthy as soil grown foods. It's so backwards though, cause people have no idea where the food they eat comes from now. We have no idea what's inside a hamburger…(54:00)…

Q: GM/VFs- which is more natural?

A: Does what humans do count as natural unequivocally, or are something's natural and something's unnatural? iPods are probably unnatural, but… organic shoelaces are somehow more natural. Dix always says farming is the most unnatural thing we do. And its true: If you look at the apple that we eat today versus the apple you find in nature, I mean it's unrecognizable. Where our apples come from are these tiny, super sour short little plants… (59:30)...And you also look at organic. People have no idea what organic means!!...

(ME: That was my thing… it is so interesting how all these ideas are starting to blend together. As people get more educated about them, at the same time the more we follow the ecological crisis that is looming, these ideas of what is natural and organic and human controlled- they all start bleeding together…) (1:00:32)

Organic is just marketing hurdle at this point, but you can't ignore that stuff. I don't think VFs are any less natural. If any thing they are more natural because they are taking a holistic approach to the human place in the world. You are giving farmland back to nature. Most of the farmland in the US would return to hard wood forest, which is a great carbon sink. We looked at the numbers and if the states of Illinois, Iowa, Kentucky, and Indiana stopped farming and just let the land go in 20 years once hardwood forests starting showing up, it would be sequestering 10% of all the US annual emissions. So that's something and it's a lot to ask from 4 states… Bio-mimickery is the word. If we can mimic eco systems

there is no such word as waste (1:03:46)… So I think the most natural thing to do is act like an eco-system and that means produce your own food and reuse your waste. Get rid of the term waste. It's gotta be circles.

Despommier returned at this point, and I resumed the interview with him.

Q: **Paleovirology… I was wondering if, to a certain extent, isolating and growing plants could have problematic affects on their health.** (02:12)

A: It's a good question. What are the affects of hermetically sealing off a plant to its future evolution? Does the plant become less resistant to natural forces because you have protected it and coddled it? And what about us? Has that happened to us, since we have learned to live inside of buildings for instance? … We are taking away our diseases by using sanitation and antibiotics. I mean, sure, let's look at the human condition and try to apply that to any other living entity. What don't we have in the Western world that the rest of countries take for granted? And the answer is: Most infectious diseases – malaria, lack of sanitation, bacterial diseases (03:20). What's the big difference then between the Western civilization and others in relation to chronic disease? They don't have any heart disease to speak of, they die too early for that. They usually don't die from cancer… (03:40) Nobody in the tropics get Crohn's disease, no body in the tropics is allergic to shell fish, nobody in the tropics has peanut butter allergies… there are no allergies in the tropics. The reason being that all of our immune system arms are directed against pathogens, which without the presence of the pathogen we still have the immune system intact and so in order to keep on red alert, basically, we do target practice and we find similar targets to the natural infections in our own tissues, and so we make what are called auto-immune diseases, and Crohn's is one of those examples. When you put those organisms back in the person, the Crohn's goes away (5:00)…*Despommier says diseases like Crohn's are "solely due" to sanitation* (06:05). Will similar things happen to plants?

Do we have examples of plants we can show changes in? We have not been doing research that long to know the answer. The only one I know of that has been kept in captivity so to speak, a part from its natural setting is a rabidopsis… This is a small flowering plant, like an African violet. But because its small and it flowers it became the object of scientific study. We have now sequenced its entire genome, we have transfected it with other genes, and it is the model for all genetic modification in other plants… So a rabidopsis… So it has changed dramatically, but let me suggest something else: No crop that we eat, none of them resemble their original parents (07:30). We have artificially selected the bigger and the better… (07:57)… If you put a plant under stress, it responds accordingly. I think you could stress a plant and make it produce the reproductive organ of your choice, namely the grain of your choice. That may or may not rearrange the plant permanently. But there is a way to compensate for this… (09:00)… *Neanderthals and humans*…(10:20)…

Appendix D:

Notes from interview with John Fisher

• John Fisher took a lecture at Harvard called *Econ. 101*… Pathetic truisms… Money makes the world go round… the fundamental question – does it make economic sense? Everything is economics… it's a social science… it's all about people and how they behave. It is related to sociology… to me, the most important characteristic so far = does it make economic sense?

• Real estate, metropolitan areas…. Farm crops.

• Not appropriate for Venture Capital community.

• What about government… maybe not in the USA because of free market principles. Inherently inefficient and wasteful…

• If it does not make economic sense, then will not happen

Me: How does technical change come about?

• Broad and complex question

• Entrepreneurship and innovation- 2 critical things: WORLD CLASS ACADEMIC INSTITUTIONS. 2) Capital formation required to finance these enterprises.

• First great example in the 20th century took place in Boston… George Dorio… collected capital started to invest in entrepreneurs and professors… most famous investment was in first mini computer (company called DEC)…On West Coast, a decade later, relocated to San Fran and began to invest in people out of Stanford…. THESE TWO PLACES HAVE BEEN POWER HOUSES (most productive and successful)

• World class scientific research plus capital

• A cultural willingness to embrace risk/accept failure – The culture that embraces risk and accepts failure does not exist…. Failure is considered a taint on your resume for the rest of your life. Europe is like this. Japan is non-existent – all very conservative societies. This is the "3rd ingredient" – cultural elements, investors that are willing to risk their money and even lose it.

• This happens more in the USA than every other country WHEN IT COMES TO PRODUCTIVITY (we are No. 1, basically)… the country that has come out of nowhere and is presenting a serious challenge is China…. They are the most entrepreneurial society on Earth. China is driving force…. The government nurtures, promotes, and enables capital formation that surpasses the US ("it's humbling") Wireless connections are better in China (also Korea and Japan) BUT USA is still leader in innovation and enterprise development.

• The Chinese have always been a country of merchants… now the government wants economic development it's true colors are shining. Hong Kong is being completely replaces as an economic center for China by Shanghai,

• Economics of VF – this is important, though clearly that is not the focus

• Book: The Structures of Scientific Revolutions (Fisher says this is "seminal book").

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