APE Scientist,

Hello again!

I hope your recent growth has been fertilized by your own interest! As we look ahead, we'll be keeping our learning on toxicity (CH17) in the background of our minds while we continue learning about how our HABITs can be harming our environment and ourselves. Today, we'll begin learning about how our FOOD HABITs impact our lives.

Whether or not your HABIT is focused on FOOD or not, it'll be interesting to see what connections you can make between food and toxicity (what chemicals, practices, etc originate in the agriculture industry which directly or indirectly harm us).

Today, your checklist schedule in APES is:

- ☐ (10 min) Discuss your article responses.
- ☐ (30 min) CH14 annots (go as far as you can in these minutes), remember to SUMMARIZE when it feels right.
- ☐ (5 min) share your annots with a partner:
    - 1+ summary
    - 1 annot you are proud of, or taught you something new
- ☐ (20 min) annotate (and begin response if time allows) Article on Vertical Farming
- ☐ (25 min) *your choice based on interest:*
    - Continue article annots and response
    - Continue CH14 annots

Your Homegrowth will be to:

- Complete annots for CH14,
- Begin and complete vocab connections for CH14

Friday will be a special day to briefly collect your questions and help you identify what to watch out for in our more formalized longer-format review(s) next week.

Much love,

Mr. Badulak

The Vertical Farm

Growing crops in the city, without soil or natural light.
By Ian Frazier

Vertical farming can allow former cropland to go back to nature and reverse the plundering of the earth.

No. 212 Rome Street, in Newark, New Jersey, used to be the address of Grammer, Dempsey & Hudson, a steel-supply company. It was like a lumberyard for steel, which it bought in bulk from distant mills and distributed in smaller amounts, mostly to customers within a hundred-mile radius of Newark. It sold off its assets in 2008 and later shut down. In 2015, a new indoor-agriculture company called AeroFarms leased the property. It had the rusting corrugated-steel exterior torn down and a new building erected on the old frame. Then it filled nearly seventy thousand square feet of floor space with what is called a vertical farm. The building's ceiling allowed for grow tables to be stacked twelve layers tall, to a height of thirty-six feet, in rows eighty feet long. The vertical farm grows kale, bok choi, watercress, arugula, red-leaf lettuce, mizuna, and other baby salad greens.When the vertical farm is in full operation, as it expects to be soon, it hopes to ship, annually, more than a thousand tons of greens.

Ingrid Williams, AeroFarms' director of human resources, lives in Orange but knows Newark well. She has degrees in labor studies and sociology from Rutgers, and she visited many of the city's public-housing apartment buildings in her previous job as a social-services coördinator. She is a slim, widely smiling woman with shoulder-length dreads who dresses in Michelle Obama blues, blacks, and whites. For a while, she had her own show, "The Wow Mom Show," on local-access TV. Through it she met many people, including a woman who is a financial expert and helps local residents with their budgets. The two became friends, and last year when this woman was giving a speech at a Newark nonprofit Williams showed up to support her.

The mini-farm's inventor, Ed Harwood, of Ithaca, New York, sold it to the Philip's Academy Charter School, in 2010. Harwood is a sixty-six-year-old man of medium stature who speaks with the kind of rural accent that sometimes drops the last letters of words. He has been an associate professor at Cornell's famous school of agriculture, and he began his career as an inventor by coming up with revolutionary improvements in the computer management of dairy cows, an animal he loves. His joyous enthusiasm for what he does has an almost messianic quality.

He first became interested in growing crops indoors in the two-thousand-aughts. Around 2003, his notebooks and diaries began to converge on ideas about how he could raise crops without soil, sunlight, or large amounts of water. That last goal pointed toward aeroponic farming, which provides

water and nutrients to plants by the spraying of a mist, like the freshening automaticsprays over the vegetables in a grocery's produce department. Aeroponic farming uses about seventy per cent less water than hydroponic farming, which grows plants in water; hydroponic farming uses seventy per cent less water than regular farming. If crops can be raised without soil and with a much reduced weight of water, you can move their beds more easily and stack them high.

Harwood solved the problem of the crop-growing medium by substituting cloth for soil. He tried every type of cloth he could think of—"They got to know me well at the Jo-Ann Fabric store in Ithaca," he said. Finally, he settled on an artificial fabric that he created himself out of fibres from recycled plastic water bottles, and he patented it. The fabric is a thin white fleece that holds the seeds as they germinate, then keeps the plants upright as they mature. The roots extend below the cloth, where they are available to the water-and-nutrients spray.

Devising a nozzle for the aeroponic sprayer proved a tougher problem. The knock on aeroponics had always been that the nozzles clogged. How he solved this Harwood won't say. He has no patent for his new nozzle. "It's more of a stream than a spray," he said, "but we're keeping the design proprietary. I have no fear of anyone copying it. You could look at it all day and never figure out how it works."

He rented an empty canoe factory in Ithaca and set up a two-level grow tower a hundred feet long and five feet wide to employ his new discoveries, along with a light system that eventually consisted of L.E.D. lights modified to his needs. He had decided to grow commercial crops and chose baby salad greens. "My 'Aha' moment came when I was in the Wegmans supermarket in Ithaca," he said. "My engineer, Travis Martin, and I looked at the greens for sale and saw that a pound of lettuce cost one dollar, while a pound of baby greens cost eight dollars. That was enough of a premium that we figured I could make my system profitable with baby greens, so I started a company I called GreatVeggies, and soon I was selling baby greens in several supermarkets in Ithaca."

When that didn't bring in enough money, he shut the company down. His financial situation, never robust, then took an upturn when an investor offered funding on the condition that he concentrate on selling the grow towers themselves, rather than the greens. Switching to that business model, Harwood formed a new company called Aero Farm Systems. He leased a number of his grow towers and sold a few. One of them went to Jeddah, Saudi Arabia, and he has no idea what happened to it. Another went to Philip's Academy, where it's the mini-farm in the cafeteria. The new company did not earn much, either, but he kept it going in a smaller part of the canoe factory.

The term "vertical farming" has not been around long. It refers to a method of growing crops, usually without soil or natural light, in beds stacked vertically inside a controlled-environment building. The credit for coining the term seems to belong to Dickson D. Despommier, Ph.D., a professor (now emeritus) of parasitology and environmental science at Columbia University Medical School and the author of "The Vertical Farm: Feeding the World in the 21st Century."

Hearing that Despommier would be addressing an audience of high-school science teachers at Columbia on a recent morning, I arranged to sit in. During the question period, one of the teachers asked a basic question that had also been puzzling me: What are the plants in a soil-free farm made of? Aren't plants mostly the soil that they grew in? Despommier explained that plants consist of water, mineral nutrients like potassium and magnesium taken from the soil (or, in the case of a vertical farm, from the nutrients added to the water their roots are sprayed with), and carbon, an element plants get from the CO_2 in the air and then convert by photosynthesis into sucrose, which feeds the plant, and cellulose, which provides its structure. In other words, plants create themselves partly out of thin air. Salad greens are about ninety per cent water. About half of the remaining ten per cent is carbon. If AeroFarms' vertical farm grows a thousand tons of greens a year, about fifty tons of that will be carbon taken from the air.

Despommier lives in Fort Lee, New Jersey, and not long after his lecture I visited him at his apartment, in a high-rise with a skyline view of New York. He is a cheerful, demonstrative man, seventy-six years old, with a short gray beard and a mobile face. The concept of vertical farming came from a class he taught in medical ecology, he said. "It was in 2000, and the students that year were bored with what I was teaching, so I asked them a question: 'What will the world be like in 2050?' and a followup, 'What would you *like* the world to be like in 2050?' They thought about this and decided that by 2050 the planet will be really crowded, with eight or nine billion people, and they wanted New York City to be able to feed its population entirely on crops grown within its own geographic limit.

"So they turned to the idea of rooftop gardening," he continued. "They measured every square foot of rooftop space in the city—I admired how they went to the map room of the public library on Forty-second Street and found aerial surveys and got their rulers out—and then they calculated what the city's population will be in 2050, and the amount of calories that many people will need, and what kind of crops can best provide those calories, and how much space will be necessary to grow those crops. Finally, they determined that by farming every square foot of rooftop space in the city you could provide enough calories to feed only about two per cent of the 2050 population of New York. They were terribly disappointed by this result."

At the time, Despommier's wife, Marlene, who is a hospital administrator, was working in midtown Manhattan. As the couple drove back and forth along the West Side Highway, Despommier considered the light-filled glass-and-steel structures, and that got him thinking about the thousands of abandoned buildings throughout the city. He began to wonder why plants couldn't live on multiple levels, as human beings do. For his next year's class he carried over the previous year's project, and this time had the students calculate what kind of structure a multilevel urban farm would need and how many people you could feed that way.

Despommier taught the class for nine more years, always asking his students to build on what previous classes had done. He began using the term "vertical farming" in the second year. For methods of indoor agriculture, he referred to technology pioneered by *NASA* and to the work that a scientist named Richard Stoner did decades ago on how to grow crops in non-Earth environments. By the class's final year, Despommier and his students had determined that a complex of two hundred buildings, each twenty stories high and measuring eighty feet by fifty feet at its base, situated in some wide-open outlying spot—say, Floyd Bennett Field, the airport-turned-park on Jamaica Bay in Brooklyn—could grow enough vegetables and rice to feed everybody who will be living in New York City in the year 2050. These vertical farms could also provide medicinal plants, and all the herbs and spices required for five different traditional cuisines.

The possibilities that opened up put stars in his eyes. Agricultural runoff is the main cause of pollution in the oceans; vertical farms produce no runoff. Outdoor farming consumes seventy per cent of the planet's freshwater; a vertical farm uses only a small amount of water compared with a regular farm. All over the world, croplands have been degraded or are disappearing. Vertical farming can allow former cropland to go back to nature and reverse the plundering of the earth. Despommier began to give talks and get noticed. He became the original vertical-farming proselytizer. Maybe the world's mood was somehow moving in that direction, because ideas that he suggested other people soon created in reality.

Today in the U.S., vertical farms of various designs and sizes exist in Seattle, Detroit, Houston, Brooklyn, Queens, and near Chicago, among other places. AeroFarms is one of the largest. Usually the main crop is baby salad greens, whose premium price, as Ed Harwood realized, makes the enterprise attractive. The willingness of a certain kind of customer to pay a lot for salad justifies the investment, and after the greens get the business up and running its technology will be adapted for other crops, eventually feeding the world or a major fraction of it. That is the vision.

Most of America's baby greens are grown in irrigated fields in the Salinas Valley, in California. During the winter months, some production moves to similar fields in Arizona or goes even farther south, into Mexico. If you look at the shelves of baby greens in a store, you may find plastic clamshells holding five ounces of greens for $3.99 (organicgirl, from Salinas), or for $3.29 (Earthbound Farm, from near Salinas), or for $2.99 (Fresh Attitude, from Quebec and Florida). Harwood's magic number of eight dollars a pound would be on the cheap side today. Four dollars for five ounces comes to about thirteen dollars a pound.

AeroFarms supplies greens to the dining rooms at the *Times*, Goldman Sachs, and several other corporate accounts in New York. At the moment, the greens can be purchased retail only at two ShopRite supermarkets, one on Springfield Avenue in Newark and the other on Broad Street in Bloomfield. The AeroFarms clamshell package (clear plastic, No. 1 recyclable) appears to be the same size as its competition's but it holds slightly less—4.5 ounces instead of five. It is priced at the highest end, at $3.99. The company plans to have its greens on the shelves soon at Whole Foods stores and Kings, also in the local area. Greens that come from California ride in trucks for days. The driving time from AeroFarms' farm to the Newark ShopRite is about eleven minutes. The company's bigger plan is to put similar vertical farms in metro areas all over the country and eventually around the world, so that its distribution will always be local, thereby saving transportation costs and fuel and riding the enthusiasm for the locally grown.

The technology it uses derives partly from systems designed to grow crops on the moon. The interior space is its own sealed-off world; nothing inside the vertical-farm buildings is uncontrolled. Countless algorithm-driven computer commands combine to induce the greens to grow, night and day, so that a crop can go from seed to shoot to harvest in eighteen days. Every known influence on the plant's wellbeing is measured, adjusted, remeasured. Tens of thousands of sensing devices monitor what's going on. The ambient air is Newark's, but filtered, ventilated, heated, and cooled. Like all air today, it has an average CO_2 content of about four hundred parts per million (we exceeded the three-fifty-p.p.m. threshold a while ago), but an even higher content is better for the plants, so tanks of CO_2 enrich the concentration inside the building to a thousand p.p.m.

The L.E.D. grow lights are in plastic tubing above each level of the grow tower. Their radiance has been stripped of the heat-producing part of the spectrum, the most expensive part of it from an energy point of view. The plants don't need it, preferring cooler reds and blues. In row after row, the L.E.D.s shining these colors call to mind strings of Christmas lights. At different growth stages, the plants require light in different intensities, and algorithms controlling the L.E.D. arrays adjust for that.

In short, each plant grows at the pinnacle of a trembling heap of tightly focussed and hypersensitive data. The temperature, humidity, and CO_2 content of the air; the nutrient solution, pH, and electro-conductivity of the water; the plant growth rate, the shape and size and complexion of the leaves—all these factors and many others are tracked on a second-by-second basis. AeroFarms' micro-, macro-, and molecular biologists and other plant scientists overseeing the operation receive alerts on their phones if anything goes awry. A few even have phone apps through which they can adjust the functioning of the vertical farm remotely.

The teacher who keeps all this machinery in good order is Catkin Flowers. That is her real given name. A tall auburn-haired woman in her forties, she starts her science students working with the farm when they're in kindergarten. "We use the farm to teach chemistry, math, biology," she explained to me one morning between classes. "The students learn with it all the way through eighth grade. I think the farm is the reason our science scores are so competitive in the state. We get the kids involved in running the grow cycles and then solving the problems that inevitably come up. That's how kids really learn, not from sitting back and watching the grownups do everything."

“We’re also teaching food literacy,” put in Frank Mentesana, the director of EcoSpaces, the school’s environmental-science program, who joined us. “Some of our kids have never seen vegetables growing. They may live in a part of the city that’s a food desert, and their families get food at McDonald’s or at bodegas. They may never have seen fresh greens in a store.”

“Kids love to grow things,” Flowers said. “It teaches them about nutrients, the minerals we put in the water, and why the water’s pH affects how the plants absorb them, and about the light spectrum, and how photosynthesis works. The kids monitor the same kind of data as AeroFarms does, but less of it, of course.”

“When we’re ready to harvest, the kids can’t wait to eat what they’ve grown,” Flowers said. “They’ll start eating the plants while they’re harvesting, and we actually have to tell them to wait because these are for the salad bar. They want to find out how they taste. And they’re excited when the plants they’ve grown become part of a meal for the whole school. Because of this farm, our school’s consumption of leafy greens is probably not met by any other school in the country.”

I thought of the tenderness of the greens this device produces—a natural simplicity elicited mainly from water and air by high-tech artifice of the most complicated and concentrated kind. It seemed a long way to go for salad. But if it works, as it indeed appears to, who knows what might come of it when we’re nine billion humans on a baking, thirsting globe? Rosenberg and I stood looking at the vertical farm in silence. On his face was a mixture of pride and love; he might have been seven years old. “We are so far above everybody else in this technology,” he said, after a minute or two. “It will take years for the rest of the world to catch up to where we already are now.” ♦

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