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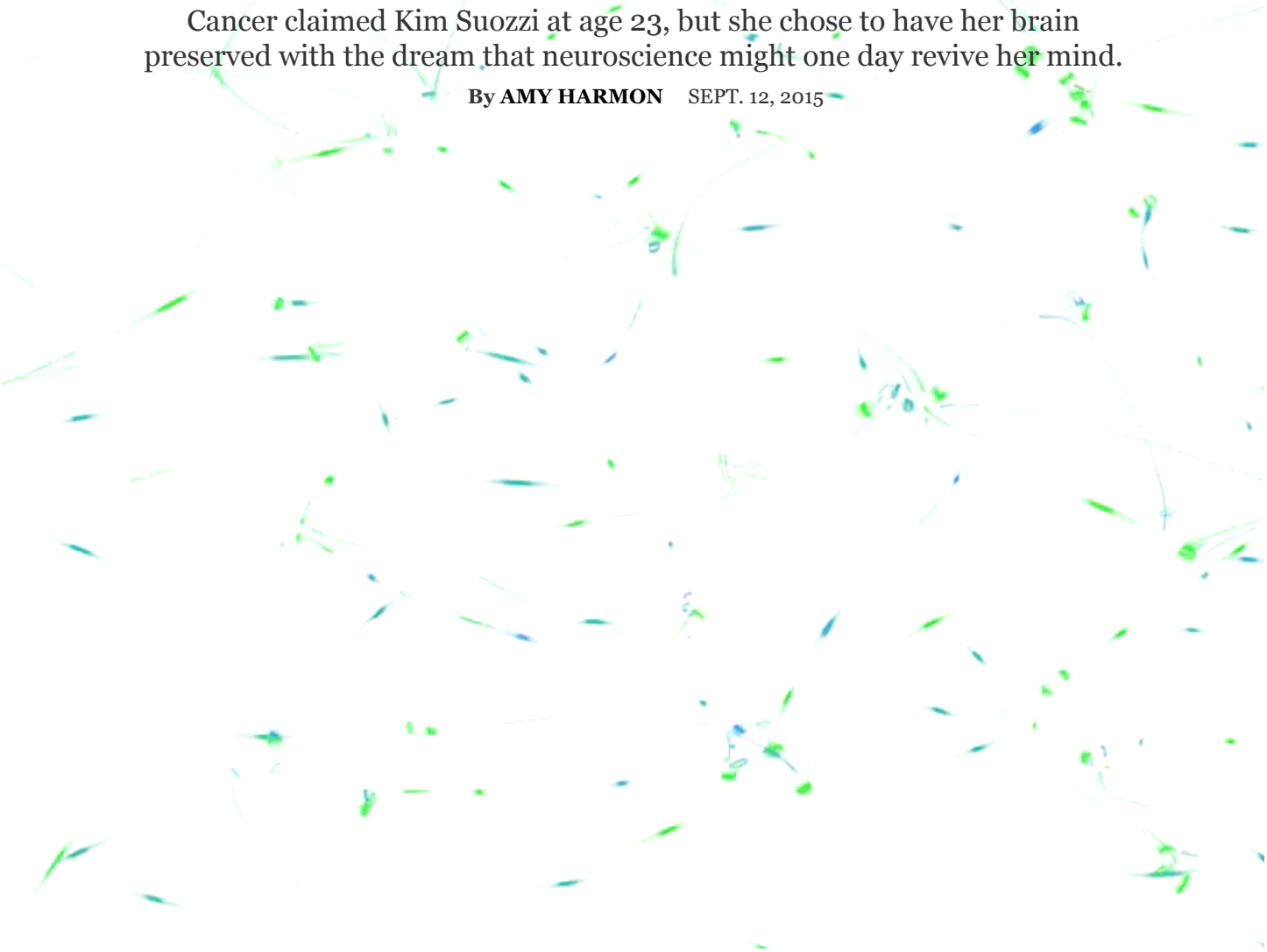
A Dying Young Woman's Hope in Cryonics and a Future

Cancer claimed Kim Suozzi at age 23, but she chose to have her brain preserved with the dream that neuroscience might one day revive her mind.

By **AMY HARMON** SEPT. 12, 2015



An artist's interpretation of neurons firing inside a brain.

In the moments just before Kim Suozzi died of cancer at age 23, it fell to her boyfriend, Josh Schisler, to follow through with the plan to freeze her brain.

As her pulse monitor sounded its alarm and her breath grew ragged, he fumbled for his phone. Fighting the emotion that threatened to paralyze him, he alerted the cryonics team waiting nearby and called the hospice nurses to come pronounce her dead. Any delay would jeopardize the chance to maybe, someday, resurrect her mind.

It was impossible to know on that cloudless Arizona morning in January 2013 which fragments of Kim's identity might survive, if any. Would she remember their first, fumbling kiss in his dorm room five years earlier? Their private jokes and dumb arguments? The seizure, the surgery, the fancy neuroscience fellowship she had to turn down?

More than memories, Josh, then 24, wished for the crude procedure to salvage whatever synapses gave rise to her dry, generous humor, compelled her to greet every cat she saw with a high-pitched "helllooo," and inspired her to write him poems.

They knew how strange it sounded, the hope that Kim's brain could be preserved in subzero storage so that decades or centuries from now, if science advanced, her billions of interconnected neurons could be scanned, analyzed and converted into computer code that mimicked how they once worked.

But Kim's terminal prognosis came at the start of a global push to understand the brain. And some of the tools and techniques emerging from neuroscience laboratories were beginning to bear some resemblance to those long envisioned in futurist fantasies.

For one thing, neuroscientists were starting to map the connections between individual neurons believed to encode many aspects of memory and identity.

The research, limited so far to small bits of dead animal brain, had the usual goals of advancing knowledge and improving human health. Still, it was driving interest in what would be a critical first step to create any simulation of an individual mind: preserving that pattern of connections in an entire brain after death.

"I can see within, say, 40 years that we would have a method to generate a digital replica of a person's mind," said Winfried Denk, a director at the Max Planck Institute of Neurobiology in Germany, who has invented one of several mapping techniques. "It's not my primary motivation, but it is a logical outgrowth of our work."

Other neuroscientists do not take that idea seriously, given the great gaps in knowledge about the workings of the brain. "We are nowhere close to brain emulation given our current level of understanding," said Cori Bargmann, a neuroscientist at Rockefeller University in New York and one of the architects of the Obama administration's initiative seeking a $4.5 billion investment in brain research over the next decade.

"Will it ever be possible?" she asked. "I don't know. But this isn't 50 years away."

There would not, Kim and Josh well understood, be any quick reunion. But so long as there was a chance, even a small or distant one, they thought it was worth trying to preserve her brain.

Might her actual brain be repaired so she could "wake up" one day, the dominant dream of cryonics for the last half-century? She did not rule it out. But they also imagined a different outcome, that she might rejoin the world in an artificial body or a computer-simulated environment, or perhaps both, feeling and sensing through a silicon chip rather than a brain.

"I just think it's worth trying to preserve Kim," Josh said.

For a brief period three years ago, the young couple became a minor social media sensation as they went to the online forum Reddit to solicit donations to pay for her cryonic storage and Kim posted video blogs about her condition.

And she agreed to let a Times reporter speak to her family and friends and chart her remaining months and her bid for another chance at life, with one restriction: "I don't want you to think I have any idea what the future will be like," she wrote in a text message. "So I mean, don't portray it like I know."

In a culture that places a premium on the graceful acceptance of death, the couple faced a wave of hostility, tempered by sympathy for Kim's desire, as she explained it, "not to miss it all."

Family members and strangers alike told them they were wasting Kim's precious remaining time on a pipe dream. Kim herself would allow only that "if it does happen to work, it would be incredible." "Dying," her father admonished gently, "is a part of life."

Yet as the brain preservation research that was just starting as Kim's life was ending begins to bear fruit, the questions the couple faced may ultimately confront more of us with implications that could be preposterously profound.

The mapping technique pioneered by Dr. Denk and others involves scanning brains in impossibly thin sheets with an electron microscope. Stacked together on a computer, the scans reveal a three-dimensional map of the connections between each neuron in the tissue, the critical brain anatomy known as the connectome.

Still arduous and expensive, the feat had so far only been performed on tiny bits of brain from euthanized laboratory animals, and it would be only one of many steps required to get to a simulation.

Moreover, the brain preservation methods scientists have used to perform such scanning, which involves encasing pieces of brain in hard plastic, had failed for anything larger than the size of a sesame seed. Nor could current methods for cooling and preserving brains at cryogenic temperatures, the only other known means to forestall decay, ensure that their fragile wiring was not damaged.

It was to clear that first hurdle, the reliable preservation of a connectome, that the brain researcher Kenneth Hayworth had formed the Brain Preservation Foundation shortly before Kim's diagnosis, with the ultimate goal of taking brain preservation into the realm of mainstream medicine.

With an advisory board that included prominent neuroscientists and $100,000 from an anonymous donor, the group was offering a prize for the first individual or team to successfully preserve the connectome of a mouse or rabbit in a way that would meet the standards of a peer-reviewed science journal.

But Kim and Josh had no time to wait. Even a poorly preserved brain, they reasoned, might be able to undergo a kind of digital repair and rehabilitation.

"I'll show you the ropes," he told her in half-mocking reference to the possibility of her return to a far-future world.

The morning she died, that meant calling again for the hospice nurse as she took her last breath.

Their Life Together

Josh, a political science major, fell in love with Kim, an agnostic science geek, shortly after encountering her freshman year at Truman State University at a meeting of the College Libertarians. There, in the fall of 2007, they bonded over a dislike for the U.S.A. Patriot Act.

Kim, whose dark good looks came from her father, had a crush on someone else. But Josh, tall, blond and self-confident — occasionally overconfident, Kim would note — persuaded her to be his canvassing partner for the presidential campaign of Ron Paul.

Soon they could be found talking into the night in an empty dormitory lounge on the Kirksville, Mo., campus, turning out the lights to keep others from entering. Often, he would coax Kim, who was studying cognitive science, to teach him about the brain.

"He asked a lot of questions," she said. "And he thought I was really funny."

For his 20th birthday, in their sophomore year, she wrote him two poems expressing her feelings for him, and by their junior year they had developed a private language of jokes and mispronounced words: "Times is hard," they once saw someone say on CNN about rising gasoline prices, and it became a refrain about matters large and small.

They first discussed the possibility of achieving a kind of immortality because of a book

assigned for Kim's cognitive science class — "The Age of Spiritual Machines" by the artificial intelligence researcher Ray Kurzweil.

Mr. Kurzweil and others who call themselves transhumanists have argued that exponential increases in computing power will generate an assortment of new technologies that will enable us to transcend our bodies and upload our minds onto a computer. He envisions an inflection point that some call the "Singularity," a singular moment when machine intelligence surpasses human intelligence.

Before Josh and Kim reached their 50s, according to Mr. Kurzweil, microscopic devices known as nanorobots inserted in the bloodstream would be able to scan brains and wirelessly upload their information.

In the event of a sudden death, you could be rebooted from your last backup. Enhancements for memory, intelligence and empathy would be available, as would the option to merge with other minds, a possibility, the couple recalled, that prompted Josh to imagine plugging into the brain of Kim's notoriously crotchety cat, Mikey.

In her term paper that year, Kim cited the criticism Mr. Kurzweil had attracted for his forecast that the Singularity would come by 2045, despite winning adherents at Google, where he has since been hired as engineering director. "His shockingly short timeline may be off," she wrote, "and perhaps drastically so."

Yet the notion that the mind is what the brain is computing, and that those computations could be simulated, was second nature to Kim, who worked as a research assistant to a cognitive psychology professor and completed a neuroscience internship at the University of Colorado the summer of her junior year. "You are a pattern of electrical signals," she would lecture Josh, perhaps adding a profanity to soften the blow.

The prospect of life in a computer simulation did not faze them: "How do we know we're not in one now?" they reasoned over cafeteria lunches. Besides, artificial body parts that could be controlled by the mind were already being tested on wounded military veterans, they knew, in a seeming prelude to robot bodies.

"Ha-ha, we'll live to Singularity!" she would exclaim.

"Hopefully we don't destroy ourselves first," Josh would concur.

But they had a plan for their nearer-term future, too. At the start of their final semester, Kim applied to a summer neuroscience fellowship as a steppingstone to graduate school. Josh was lining up a job as a legislative assistant to a Missouri state representative, but promised to get a job in politics wherever she landed. Eventually they would have a child, Kim agreed after some

lobbying.

The headaches started that winter. "Can you find the Advil and bring it to campus?" she messaged Josh one afternoon. Then came the seizure. Kim was in a friend's car, returning to Kirksville after spending midwinter break at her mother's home in a St. Louis suburb, when she found it difficult to talk.

She looked at her hand and felt as if it was no longer part of her body. She went to the hospital and she and Josh spent the better part of the following weeks at Barnes-Jewish Hospital in St. Louis.

"Good news: got into The Center for Behavioral Neurosciences' BRAIN summer program," Kim announced on Facebook in mid-March, 2011, after a series of M.R.I. scans revealed a tumor her doctors believed would be benign. "Bad news: a tumor got into my BRAIN."

It was Josh who told her she had cancer, after she awoke from surgery to remove the tumor. "Are you kidding?" she asked him, three times, until she could tell he was not. They learned a few weeks later that the tumor was glioblastoma, a virulent and incurable form of the disease.

The median survival time for patients like Kim, treated with standard radiation and chemotherapy, was less than two years. Unless she responded to an experimental drug, they were told, she would likely have a period of remission after which the tumor would recur and her decline would be swift.

Josh's Facebook status the week of her diagnosis in April read simply, "Damn."

A Prize for Brain Preservation

The fundamental question of how the brain's physical processes give rise to thoughts, feelings and behavior, much less how to simulate them, remains a mystery. So many neuroscientists see the possibility of reproducing an individual's consciousness as unforeseeably far off.

"We have to recognize that there are many huge gaps that have to be leaped over," said Stephen J. Smith, a neuroscientist at the Allen Institute for Brain Science in Seattle. "The brain is holding on to many of its secrets."

Jeffrey Lichtman, a Harvard University neuroscientist, said, "Nothing happening now is close to a reality where a human patient might imagine that their brain could be turned into something that could be reproduced in silico."

But in the spring of 2011, as Kim began chemotherapy that caused hives to erupt all over her

body, an unusual letter appeared in Cryonics magazine. Titled "The Brain Preservation Technology Prize: A challenge to cryonicists, a challenge to scientists," it argued that if a brain was properly preserved, time would not be an issue.

The magazine is published by the Alcor Life Extension Foundation, the larger of two United States cryonics organizations. Founded in the 1970s, Alcor is best known for storing the frozen head of the baseball great Ted Williams, along with some 140 others who hoped to one day be revived. The foundation, a nonprofit, has about 1,000 members who have made financial arrangements to undergo its preservation procedure upon death.

Dr. Hayworth, then a postdoctoral researcher at Harvard, had written the letter to introduce the Brain Preservation Technology Prize. Perhaps the only mainstream neuroscientist to openly acknowledge that he would like to upload his brain to a computer someday — and to argue that there would be broader social merits to the practice — he counted himself a "skeptical member" of Alcor at the time.

"Why destroy the wisdom we build up individually and communally every generation if it's not necessary?" he prodded reporters, fellow scientists and potential donors.

If the connectome, laid down by genes and altered by life experience, turns out to be the repository of the identity information that neuroscientists widely believed it to be, he argued, there was no reason that uploading a mind should not ultimately succeed, "especially when we can now see how to save it by expanding on today's neural mapping technology."

Once described by The Chronicle of Higher Education as "an iconoclast with legitimate research credentials," Dr. Hayworth had helped to invent one of the existing variations of that mapping technology, and later in 2011 would take a position as senior scientist at the Howard Hughes Medical Institute to improve on another.

While it is widely agreed that the connectome encodes our unique memories and learned behaviors, Dr. Hayworth's belief that a map of the brain's synapses could one day be sufficient to reconstruct a mind is controversial.

Accurately simulating a functioning brain from a static circuitry map, many scientists say, will require a grasp of how living brains work that is orders of magnitude better than what we have today. Even then, it may be necessary to identify the molecular identity of each neuron, in addition to knowing how they connect to one another.

Moreover, to scan and analyze a human connectome with today's technology would cost billions of dollars and take thousands of years. And of course, no one knows if even a perfect simulation of a mind would retain the self-awareness of the original.

In an indication of the prevailing skepticism, Dr. Hayworth had been unable to garner a substantial purse for his prize.

The venture capitalist Peter Thiel, for instance, who has acknowledged being a member of Alcor — "Cryonics only seems disturbing because it challenges our complacency about death," he has said — declined to underwrite the prize.

But an anonymous donor offered $100,000 after hearing Dr. Hayworth's pitch in a 2010 speech at a conference in Cambridge, Mass. Now Dr. Hayworth had enough to award a $25,000 prize for a small mammal brain — a rabbit or mouse — and reserve $100,000 for a larger one, likely a pig. And he already had one competitor, Shawn Mikula, then a postdoctoral researcher at the Max Planck Institute.

The entries were to be judged by other neuroscientists who would examine portions of the preserved brains with an electron microscope. To win, a description of the technique would also need to be accepted for publication in a peer-reviewed scientific journal.

The challenge for the competitors was how to preserve a brain for scanning — by chemicals or cold.

Under Dr. Mikula's method, called chemopreservation, neuroscientists first insert a needle filled with a chemical fixative into an anesthetized animal's heart while it is still alive to pump the fixative through the brain, essentially gluing its structure in place. The brain is then soaked in a heavy-metal stain so the neurons can be seen under an electron microscope, drained of water, and embedded in a hard plastic.

That method has the considerable benefit of allowing for storage of the brain at room temperature. But some neuroscientists argue that the chemicals erase information that would be required to devise an accurate simulation of the brain.

The decades-old practice of cryonics, by contrast, in which human brains and bodies are stored at somewhere below minus 300 degrees Fahrenheit, has since the late 1990s employed a thick, viscous antifreeze to replace the blood and water in the brain in an effort to preserve it before storing it.

The antifreeze is needed to avoid the formation of jagged ice crystals between brain cells that can tear through the fragile web of the tissue. But since cryonics can begin only after a formal declaration of death, clots can form and vessels can start to collapse before the process is started. Even with no delay the liquid can take hours to circulate.

Some proponents of this procedure, known as cryopreservation, have long wanted brains preserved for uploading to a computer. But most proponents hope that the biochemical damage

to brain cells will one day be reversible, allowing brains to be thawed and repaired.

Still, the reliance on strictly hypothetical technology for the idea of biological repair led one critic to dismiss cryonics as "based almost entirely on faith in the future" in a 2001 Scientific American essay.

In his letter, Dr. Hayworth said the prize competition could change this. "Once the first teams begin to show real progress toward winning the prize," he wrote, "I fully expect to see a watershed change in attitude toward the idea of cryonics within the scientific community as a whole."

'We Don't Live Forever'

Kim spent what seemed likely to be her last year of life trying not to be preoccupied with death. While Josh commuted to his job in the state capital from the small house they rented in Columbia, Mo., she volunteered in a neuroscience laboratory at the University of Missouri, restricted herself to a low-sugar diet and started a cancer blog in which she sought to parody the form.

"I want to make a little widget for the top of the page that says IS KIM ALIVE?" she wrote her friend Abby Neidig in a Facebook message. "And it'll say 'yes,' unless I'm dead. Then it will say 'nope, sorry. I hope this isn't how you found out.' "

"I think it's pretty funny," she insisted.

As her condition worsened, Kim and Josh fielded a flood of kind offers from fellow users of Reddit, where Kim had posted about her condition: a week in Cape Cod, airline tickets to Australia, seemingly unlimited illegal drugs.

Even though they knew the chances were vanishingly small, they could not help but hold out hope that the tumor would not return, or that a clinical trial drug would help her. Kim had tried to ward off ordinary thoughts of the future, she wrote to a friend, Kailey Burger, but sometimes they would creep in anyway, like when she found herself thinking "I'm gonna get one of those fridges with the freezer drawer on the bottom when I'm a real adult."

But the tumor reappeared on an M.R.I. in the spring of 2012, and Kim and Josh knew that her year of remission was over. The right side of her body was beginning to weaken. Soon she would be unable to grasp things, write, or play a favorite video game, "Ocarina of Time."

That the tumor had returned in her brain stem meant it could not be operated on, excluding her from the most promising experimental drug trials. On the other hand, because that region of the brain controls basic bodily functions like breathing, "I will likely die before the tumor spreads

to the areas central to who I am," she wrote on Reddit, where she had posted of her condition.

Kim had had an interest in cryonics since reading about it in Mr. Kurzweil's books. But she knew that it was expensive and that the most common way to pay for it, taking out a life insurance policy for the amount of the fee, was not an option for a previously uninsured 22-year-old with terminal brain cancer.

She had hesitated to raise the prospect of paying for it with her father, Rick Suozzi, a medical device sales representative. Even some of her supportive circle of friends had seemed unsure of what to say when she sounded them out about it: Until Kim brought it up, one friend thought it was a fiction invented by the creators of "Futurama," the animated television series whose "accidentally cryopreserved" protagonist wakes up in the future.

"It freaks people out," she told Josh.

And when she finally did talk to her father, in an airport lounge in June 2012, his refusal came as a rude awakening.

Over the year, Mr. Suozzi offered to send the couple on a vacation. "Is there anything you'd like to do together?" he asked. "Go to Europe, go on a cruise?"

But like many people, Mr. Suozzi knew of cryonics mostly as the butt of late-night talk show humor.

When she told him what she wanted he simply shook his head.

"I can't help you with this," he said. "We don't live forever, Kim."

In what Mr. Suozzi recalls as a heated conversation, Josh called to urge him to reconsider. "What are you saying?" Josh demanded. "Should we just give up on trying to treat her cancer now, too?"

"If you want to do this," Mr. Suozzi replied, "You're going to have to figure out how to do it yourself."

A Last Resort

They had one other idea of how to raise the money.

Reddit, whose far-flung and highly opinionated members were known for coming to the aid of those whose plight struck a collective chord, had loomed as a possible last resort since the outpouring of support at her earlier post about cancer.

"But why would anyone donate?" she demanded of Josh. "There's no compelling reason why I deserve another chance at life."

"You can say that then," he insisted. "Let people make up their own mind."

First, though, in the two weeks that followed, they decamped to Hope Lodge, an American Cancer Society facility for patients being cared for at the Dana-Farber Cancer Institute in Boston, where Kim was admitted to a trial of a long-shot experimental drug.

There, in between Kim being pricked and prodded, they focused on what it might take to preserve and reconstruct her mind.

They read academic journal articles on neuroscience, online forums and the Alcor website. The foundation, they learned, encourages customers to choose what it calls "neuropreservation," or preserving just the brain, as opposed to freezing their entire body. Given the imperative for speed, the logic went, it was better to focus everything on the brain.

"If I get frozen I will get my head chopped off," Kim told her friend Ms. Neidig matter-of-factly. "It's cheaper, and apparently it gets the juice in there faster."

And the idea of a disembodied Kim was O.K. with Josh: "I wasn't planning on leaving her when she got old and saggy," he observed.

If the $80,000 fee for neuropreservation seemed steep, they learned that about a third of it pays for medical personnel to be on call for death, while another third is placed in a trust for future revival. The investment income from the trust also pays for storage in liquid nitrogen, which is so cold that it can prevent decay in biological tissue for millenniums.

Some of what they found out gave them pause. Alcor's antifreeze, once pumped through the blood vessels, transitions into a glassy substance before ice can form and do damage. The process, called vitrification, is similar to that used to store sperm, eggs and embryos for fertility treatments. But that glassy substance has been known to crack, likely causing damage of a different kind.

And the infinite scenarios could seem overwhelming. Might she be back in a hundred years, or a thousand? Would Josh be there? In what form? If damaged, maybe her biological brain could actually be repaired?

In the context of Hope Lodge, the prospect of cryonics did not seem to them so different from the clinical trials that hundreds of cancer patients were participating in with only the tiniest chance of success at enormous expense.

Even with an ideal cryopreservation, the damage from her tumor would need to be repaired. And they were aware that her brain would most likely sustain more damage from the procedure itself.

But part of her brain, Kim pointed out, had already stopped working and she still enjoyed life. And like brain-damaged patients, she felt she could be rehabilitated. In fact, digital repairs might well be easier than physical recovery. There was already some neuroscience research that made piecing together a damaged connectome seem conceivable.

Memories, for instance, appear to be stored in multiple places. Certain areas of the brain responsible for tasks like attention might be replaced with off-the-shelf spare parts. The molecular identity of neurons held clues to which should be connected where. And broken ones might be digitally pieced back together, perhaps not even precisely, some researchers say.

"You'd ask yourself how many mistakes could you make and still have the same person," Joshua R. Sanes, director of the Center for Brain Science at Harvard University, said in an interview. "The ability of us to keep being ourselves in the face of changes in our nervous system is pretty amazing."

Kim tried to make light of it all. "You'll have to enhance me," she told Josh. But she was serious when she told him she would rather survive in some damaged form than not at all.

Amid the few fantasies they allowed themselves, Kim made a point to tell him something more tangible, too: "I want you to be happy," she said. "You'll find a new person, and you'll be O.K."

When an August M.R.I. showed that the experimental drug had failed to halt the growth of Kim's tumor, she and Josh shot and edited a short video for her blog, in which she asked for donations for cryonics.

"Get ready to feel weird about me!" she posted on Facebook with a link.

The next day, as they drove across the country to Duke University in Durham, N.C., where Kim was to receive radiation, she wrote out a longer explanation: "Reddit, help me find some peace in dying young (I'm 23)," it read.

Josh rummaged for a pen, one hand still on the wheel. He scrawled "Freeze Me, Reddit," on a stray piece of paper and handed it to her.

She took a picture of herself, embedded it in her post and clicked "send."

Sympathy and Cynicism

In the first wave of response, Kim wrote to a friend, "Reddit was harsh."

Hundreds voiced or linked to opinions over the course of a few days, more after Kim was featured on the local television news. The couple were prepared for the technical objections about cryonics and uploading minds.

They even took a certain pleasure in the philosophical argument over whether any uploaded mind would essentially be a zombie, with all the behaviors of the original but lacking its soul.

Some recoiled at the prospect of living much longer lives, citing fear of boredom, or being useless, or lonely. Others suggested the future would have little interest in relics from the 2010s ("you'd be little more than a rodent to them, intelligence-wise," one wrote).

But it was the hostility, as though they were proposing a Faustian bargain for all of humanity, that took Josh and Kim aback.

One commenter vowed to donate money to cancer research, "not your extraordinary long-shot attempt at self-preservation." Another called Kim a "selfish retard."

Josh voted down the online critics and feigned keeping his temper.

"Some people who enjoy life fight for any chance to keep living," he replied to a post that suggested Kim should spend her remaining time "actually living your life."

Still, Kim's original post was "upvoted," akin to "liking" on Facebook, 89 percent of the time, a hit in Reddit terms.

And they were floored by the outpouring of support from strangers.

A software engineer at Google, Maksym Taran, who like Kim was 23, donated $1,000 within hours and wrote a few days later that he would supply the full amount if she failed to raise it. Another donor was Michael Andregg, then 36, co-founder of Halcyon Molecular, a high-profile genetics start-up in Silicon Valley: "I hope you preferably get better," he wrote to her, "but failing that get cryopreserved."

Parijata Mackey, a young woman in California, connected her to a board member at Alcor, and sent her phone number: "If you're ever bored, or want to chat about cryo-sciencey-future things, feel free to call me anytime."

A group of longtime cryonics supporters, the Society for Venturism, pitched in, as did Kim's mother, Jane Suozzi, who signed over a $10,000 life insurance policy she held in Kim's name.

As donations continued to come in and their contacts at Alcor indicated that Kim would almost certainly be fully funded, Josh sat her down to shoot a thank-you video.

A Gathering of the Like-Minded

Adamant about not having a "bucket list," Kim nevertheless admitted to a certain interest in seeing the Grand Canyon, and in October 2012, she and Josh set out to visit it on a road trip. But first they stopped at a cryonics conference Alcor was holding to celebrate its 40th anniversary in Scottsdale, Ariz., at which she had been invited to speak.

The conference was full of well-wishers, including several who had donated money to her. And Kim was looking forward to the talk by Sebastian Seung, a Princeton University neuroscientist who had treated cryonics seriously in his book published that year, "Connectome: How the Brain's Wiring Makes Us Who We Are."

If the brain's connections remain intact in the cryonics procedure, or can be pieced back together, he had written, "then we cannot rule out the possibility of resurrecting memories and restoring personal identity."

But Dr. Seung, an adviser to the Brain Preservation Foundation, cautioned Alcor members that he hoped his talk would help them "make informed decisions"

Even though three-dimensional maps of partial bits of brain had become relatively easy to produce, Dr. Seung observed, Alcor had not published any such images — even of animal brains preserved under its protocol. Only two-dimensional images had been published. That raised questions about how well preserved their clients' brains were.

Soon a heated argument ensued among some audience members over how to preserve brains.

Greg Fahy, the chief scientist at 21st Century Medicine, the company that invented the cryoprotectant Alcor uses to protect the brain from ice crystals, defended Alcor's methods, pointing out that no method was available that could achieve connectome preservation using fixation and plastic embedding of a human brain, so that no evidence for that approach existed either.

Dr. Fahy, a cryobiologist whose research focuses on organ banking, had provided the most encouraging signs that cryonics did preserve brain structure. In a 2009 experiment, his team showed that neurons in slices of rabbit brains immersed in the solution, chilled to cryogenic temperatures and then rewarmed, had responded to electrical stimulation.

His method, he contended, preserved the connectome in those slices. But a complication prevented him from entering the prize competition: Brain tissue perfused with the cryoprotectant invariably becomes dehydrated, making it nearly impossible to see the details of the shrunken neurons and their connections under an electron microscope.

Dr. Hayworth, the founder of the Brain Preservation Technology Prize, argued that a slice of brain responding to electrical stimulation was unconvincing evidence that the critical connections throughout the whole brain had been preserved.

Yet the only competitor so far for his prize — Dr. Mikula of the Max Planck Institute — had also experienced difficulty in the key step of his method that would allow the tissue to be seen under an electron microscope.

So Dr. Hayworth urged Dr. Fahy to find some way for his work to be better validated. "We have to be able to see it to believe it," he said.

In fact, there was one way Dr. Fahy had considered. He could fix the brain's structure in place with chemicals first, just as Dr. Mikula was doing, buying time to perfuse the cryoprotectant more slowly to avoid dehydration. But he lacked the funds, he said, for a project that would have no practical business application for organ banking. Also, his company's focus is on what he calls "reversible" cryopreservation, whereas fixing the brain's structure in place with chemicals, as is done in chemopreservation, would place biological revival, the goal of many Alcor members, even farther out of reach.

Kim's talk was well-received. Josh, watching from the audience, felt warmed by the applause that broke out several times during her short presentation. Yet he noticed her losing her train of thought more than once.

Inevitable Complications

In early November, Kim assigned her power of attorney to Josh. She understood, Josh later realized, better than he had, how little time she had left.

"I know that, Mom and Dad, you probably would respect my last wishes," she said to her phone camera. "But Josh knows me best."

Josh, who one year granted Kim's birthday wish to dress her, now dressed her every day.

They had decided that Kim would die in the hospice Alcor had suggested near its headquarters in Scottsdale, one that would allow the cryonics team to be on hand with all its equipment so the preservation procedure could begin immediately. And after a sharp exchange, in

which her father threatened to take Kim home with him to Florida, Mr. Suozzi backed down.

"Josh and I have only one thing in common," Mr. Suozzi said with a certain reluctant admiration. "And that is our love for Kim."

Kim decided to refuse food and water to hasten her death before the tumor consumed more of her brain. But 12 days after her arrival at the hospice — far longer than they had imagined would be necessary — the hospice informed them that because her condition seemed to have stabilized she would have to be treated as an outpatient.

Alcor's emergency medicine technician was prohibited from touching Kim before her death was officially pronounced by a medical professional. When Josh protested, the hospice assured him that the nurse would get to the apartment Mr. Suozzi rented nearby in less than 15 minutes.

But when, two days after Kim had left the hospice, Josh did call at 5 a.m. to say she was dying, it took an hour for one of the nurses to respond because, he was told later, they were between shifts.

When it did begin, the procedure itself went mostly as planned. With the help of two nurses employed by Alcor, the company's emergency medical technician, Aaron Drake, performed a series of steps designed to keep the blood vessels in Kim's brain from collapsing.

He connected her to a CPR device to restore the circulation of her blood. A tube was inserted into her lungs to deliver air. She was given medications to prevent the brain from swelling and to break up blood clots. Then she was lowered into an ice bath and carried to the van for the short drive to Alcor's facility.

By late morning, her head had been separated from her torso. Josh watched from an observation window as the cryoprotectant was pumped through her main cerebral arteries.

When all that remained was to continue the cooling with liquid nitrogen gas, Josh looked into her face for the last time. They had done, he thought, the best they could.

Preserving Her Spirit

Josh grieved for Kim in the usual ways, but also in some unusual ones.

He had promised to periodically leave her messages so she could catch up on what she had missed, and he did.

He reclaimed the job he had quit to care for Kim in the months before her death. He began to

rebuild the ties to family and friends that he had neglected while Kim was dying and sought, as Kim had once put it, to "find a new person."

When a CT scan of Kim's brain arrived from Alcor, it appeared to show that the cryoprotectant had reached only the outer portion of her brain, leaving the rest vulnerable to ice damage.

Josh took some solace in the fact that the outer layer, associated with abstract thinking and language, appeared to have been protected.

He holds out hope of seeing Kim again someday. "Until (or unless) the day comes that Kim can be brought back," he wrote on her Facebook page, "remember her, celebrate her, and emulate her resilience, so we can create the future of her dreams."

Kim's father sometimes leaves her voice mail messages too, just in case, he said, she does turn out to be around to hear them.

"Kim, it's Dad," they often start, "I just wanted to leave you a message."

Brain preservation research went on too.

In the late fall of 2013, almost a year after Kim's death, a celebrity D.J., Steve Aoki, announced a benefit for brain research.

Of four charities Mr. Aoki identified, the one to register the most "likes" on his Facebook page over the following month would receive $1 from every ticket of his tour, likely to total some $50,000. One of them was Dr. Hayworth's Brain Preservation Foundation.

Soon the foundation had won the contest. Of its winnings, $20,000 went to Dr. Fahy to enable him to try the new protocol he had proposed, first fixing the connectome in place with chemicals so that the brain did not shrink from dehydration and slices of it could be viewed under an electron microscope.

Dr. Mikula also got some of the money and made progress. He discovered the one solvent among hundreds that allowed him to complete the task of staining a whole mouse brain and preserving it in plastic. The technique, he wrote in an email, can "likely be adapted to human brains within five years."

The journal Nature Methods published his protocol in April. And this month, a paper by Dr. Fahy and a colleague at 21st Century Medicine, Robert McIntyre, was accepted for publication by the journal Cryobiology. It includes electron microscope images of a rabbit and pig brain preserved under their method.

Both groups have submitted their work to the Brain Preservation Technology Prize.

Illustrations by Santtu Mustonen

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