HOW MUCH MONEY ARE YOU WIRED FOR? ILLUSTRATION BY BRIAN REA. ANIMATION BY DELCAN & COMPANY

IN 1999, a trio of economists emerged from a conference at the University of California, Los Angeles, squinting without sunglasses in the unfamiliar sun, and began a slow walk through the hills overlooking the city. The three of them — a Harvard economist-in-training, Daniel Benjamin, and the Harvard economists Edward Glaeser and David Laibson — were reeling. They had just learned about a new field, neuroeconomics, which applies economic analysis to brain science in an effort to understand human choices. Now they were strolling through the taxonomy of midday joggers and dog-walkers in Los Angeles, talking all the while about how people become what they are. Benjamin recalls feeling very out of place. "Everyone was so beautiful," he says.

The economists spent the walk discussing what else they could measure across such a wide variety of human beings. By the time the sun began to set, the conversation landed on the very building blocks of life. "If economists are studying the brain," Laibson asked, "what about studying genes?"

At that time, the standard method for connecting genes to human outcomes was to look for connections between specific DNA clusters and specific conditions in the lives of people who share those genes. B.R.C.A., perhaps the best-known gene sequence in medical science, is associated with a high risk of breast cancer. The A.P.O.E. sequence seems to have a connection to your chances of developing Alzheimer's. "We thought we were going to find a few candidate genes that were the critical genes for impulse control or risk taking or cognitive ability," Benjamin says. But when Benjamin, Glaeser and Laibson began writing to the keepers of DNA databases, asking to partner up, they found the geneticists reluctant to join forces. And matching D.N.A. to social outcomes, like educational attainment or wealth, wasn't just ethically questionable, it was practically impossible. This was before the Human Genome Project had fully sequenced human DNA, so there just wasn't enough data to map it to the simplest biological outcomes, much less the subtler behavioral outcomes economists like to study.

Today, Glaeser is best known for studying cities. Laibson's work is focused largely on behavioral economics. But Benjamin has remained committed to

genes, and in 2007, as genome data became cheaper and more plentiful, a new method for connecting genes to outcomes emerged: genome-wide association studies (G.W.A.S.). With the candidate-gene method, you had to essentially guess which genes might be involved, and usually got it wrong. "With G.W.A.S., you look at the whole genome and let the data tell you where there's variation," Benjamin says.

Once a G.W.A.S. shows genetic effects across a group, a "polygenic score" can be assigned to individuals, summarizing the genetic patterns that correlate to outcomes found in the group. Although no one genetic marker might predict anything, this combined score based on the entire genome can be a predictor of all sorts of things. And here's why it's so useful: People *outside* that sample can then have their DNA screened, and are assigned their own polygenic score, and the predictions tend to carry over. This, Benjamin realized, was the sort of statistical tool an economist could use.

The first scientists to combine G.W.A.S. and polygenic scores used them to find associations with health outcomes. A 2009 study used polygenic scoring to assess the genetic risks of schizophrenia. Further studies created polygenic scores for everything from multiple sclerosis to height. The scores aren't individually predictive, and the associations are statistically small, but for geneticists, they're a powerful tool for studying medical outcomes across large groups.

As an economist, however, Benjamin wasn't interested in medical outcomes. He wanted to see if our genes predict social outcomes.

In 2011, with a grant from the National Science Foundation, Benjamin launched the Social Science Genetic Association Consortium, an unprecedented effort to gather unconnected genetic databases into one enormous sample that could be studied by researchers from outside the world of genetic science. In July 2018, Benjamin and four senior co-authors, drawing on that database, published a landmark study in Nature Genetics. More than 80 authors from more than 50 institutions, including the private company 23andMe, gathered and studied the DNA of over 1.1 million people. It was the largest genetics study ever published, and the subject was not height or heart disease, but how far we go in school.

The researchers assigned each participant a polygenic score based on how broad genetic variations correlated with what's called "educational attainment." (They chose it because intake forms in medical offices tend to ask patients what education they've completed.) The predictive power of

the polygenic score was very small — it predicts more accurately than the parents' income level, but not as accurately as the parents' own level of educational attainment — and it's useless for making individual predictions. Like other G.W.A.S., this one reveals patterns but doesn't explain them.

And with a data set this big, the patterns provide a lot of information. The authors calculated, for instance, that those in the top fifth of polygenic scores had a 57 percent chance of earning a four-year degree, while those in the bottom fifth had a 12 percent chance. And with that degree of correlation, the authors wrote, polygenic scores can improve the accuracy of other studies of education.

For 19 years, Benjamin and his colleagues were looking for fundamentals. Now, they say, they've found them. The genes with which you are born travel during your life through a mediating layer of biology and social experience — racism, puberty, vacations, illness, industrial accidents, sexual harassment, poverty, divorce — that seems so complicated as to be unmeasurable. But their study, part of a field now called "geno-economics," claims to measure, in part, the degree to which our genes determine who we become. How is that possible? And in an era of dramatic political divisions, predatory companies and systemic inequality, should we really be mapping genetics to social outcomes?

THE LIST OF authors on Benjamin's study is like an academic bus crash: sociologists and economists jumbled with epidemiologists, psychiatrists and geneticists. But Dalton Conley, a professor of sociology at Princeton, is perhaps the most personally and professionally complicated jumble of them all.

"I grew up as a white kid in a largely African-American and Latino neighborhood full of housing projects," Conley says. "My parents were lefty artists. At a certain point they lied about our address to move me to a public school in Greenwich Village, so I had a daily commute across the socioeconomic landscape." In his memoir of that childhood, "Honky," Conley writes that almost immediately he knew that "based on the color of my skin, I would be treated a certain way." The social power of certain genes was obvious to him, he writes, because "some kids got unique treatment for being taller or heavier than everyone else, but being whiter than everyone else was a different matter altogether."

Conley describes his early academic work as "lefty sociology." His Ph.D. thesis was on the black-white wealth gap and he dedicated his early career to studying the transmission of health and wealth between parents and children.

At N.Y.U., Conley kept getting into disagreements with geneticists, arguing that their methods were dangerously naïve. It seemed to him implausible that studying only twins — the gold standard of genetics research — was enough to teach us the difference between nature and nurture. But over time, he decided that it wasn't enough to just argue. Conley is an academic, and even within that tortured group he is something of a masochist. At that time he was a tenured professor, the kind of gig most people see as the endgame of an academic career, and yet he decided to go back and grind out another Ph.D., this time in genetics. He went into his program believing that our social environment is largely the cause of our outcomes, and that biology is usually the dependent variable. By the end of his time, he says, the causal arrow in his mind had pretty much flipped the other way: "I tried to show for a range of outcomes that the genetic models were overstating the impact of genetics because of their crazy assumptions." He sighs. "But I ended up showing that they're right."

Now he says he's convinced the benefits of studying polygenic scores are worth the risks. "I still have some queasiness about what can be done with this research, how politically explosive it can be," he says. "But as someone who wants to drill down into human behavior, I don't think we can ignore it anymore."

Benjamin and his co-authors included a long F.A.Q. document that carefully explained the limits of their findings, not least that they shouldn't be used to create some sort of half-baked genetics-based educational policy. And the authors I spoke with talk openly about the risks that their work will be misinterpreted or misused, but they also speak of a desire to use polygenic scores to find genetically predetermined social gaps and compensate for them by other means. It's a theme I've heard often in academic circles: If we can measure a gap in society, we can close it. (In a 2017 book, "The Genome Factor," Conley and his co-author Jason Fletcher even propose the idea that genetics could someday be used to build not just personalized medicine, but personalized *policy* that takes into account the genotypes that influence whether you and I are receptive to certain methods of instruction, or punishment, or therapy.) But Marcy Darnovsky, executive director of the Center for Genetics and Society, argues that by

measuring these social gaps, well-intentioned academics have in the past inadvertently pointed them out to those who want to exploit the gaps, or even make them wider. "Alfred Binet's idea was that we were going to use his I.Q. tests to find kids who need special learning environments so we can help them do better," she says. "But soon, applying I.Q. tests was part of the eugenics movement in the United States. These things have real effects. And right now we're talking about introducing these ideas in a time of increasingly blatant xenophobia and white supremacy."

If what Benjamin's study claims to measure is controversial, consider what it doesn't measure. The study only draws on the DNA of white people — Europeans, Icelanders, Caucasians in North America, Australia and the United Kingdom. And that's in part because only those groups, along with Chinese nationals, have given over their D.N.A. in large enough numbers to achieve the statistical power that geno-economics researchers need. I shared Benjamin's paper with Jesus Hernandez, an urban sociologist who spent 30 years working for the state of California and at the University of California, Davis, and now runs his own research firm mapping the distribution of things like transportation, housing and education to predict social outcomes. Later, when I reached him by phone, he laughed bitterly. "We *always* do white people first," he says, "because it's easiest. It's the cleanest bill of goods. They all have more like experiences. When we start testing out how to deliver a transit project, we'll put it in a white neighborhood first, because we're going to make sure that it works. Does it meet the needs of a minority neighborhood? Hell no. But we're going to put it there anyway, because it worked in this neighborhood. This is our thinking, and this kind of thinking perpetuates the scientific view, which is 'Science is pure!'"

But even if the same numbers of people from all races provided their data, one group would still have to be excluded from the study: people with recent genetic roots in Africa, which is to say both Africans, African-Americans and many Latinos. This racial exclusion has to do with the origins of modern humans. When a group of people on what is now the continent of Africa decided, some 50,000 to 70,000 years ago, to go see what the rest of the world was about, they formed what geneticists call a "population bottleneck." The small group that walked off the continent formed the small gene pool from which all non-African people — whether a Caucasian or a Han Chinese — descend. So the genes of people within the much larger, much more ancient gene pool of Africa (including those brought to the United States and elsewhere by slavery) are so much more

diverse that researchers would need a far larger sample — at least two or three times as large, Benjamin says — to even have a hope of finding measurable patterns. Benjamin and his collaborators in fact tried applying the polygenic score derived from European DNA to African-Americans and found the method didn't work well enough to be useful.

Benjamin says he knows others will be tempted to try to use this method to compare genetic advantages between races, but "that would be a misuse of the data. You just can't do that sort of comparison." But the good intentions of Benjamin and others in his field depend on being able to use their method on everyone, or no one. Several researchers involved in the project mentioned to me the possibility of using polygenic scores to sharpen the results of studies like the ongoing Perry Preschool Project, which, starting in the early 1960s, began tracking 123 preschool students and suggested that early education plays a large role in determining a child's success in school and life. Benjamin and other co-authors say that perhaps sampling the DNA of the Perry Preschool participants could improve the accuracy of the findings, by controlling for those in the group that were genetically predisposed to go further in school. But the participants in that study are black, which means they come from a gene pool that polygenic scoring can't yet handle. So in the meantime, will only white people's educational standards be raised by this work? And if so, will the policy benefits for white people measured by geno-economics carry over to other groups?

EVEN NOW, AS scientists debate the ethics of this early research, the free market is ready to sell whatever it can. The seeming precision of "genetics" is irresistible, especially for those of us facing the stomach-churning uncertainty of disease, aging or new parenthood. This summer, I was approached by the representatives of a fertility clinic seeking to publicize a new product, "the ability for parents to select eye color in their babies." And soon I was on the phone with Dr. Reza Radjabi, the founder and chief executive of Ferny, a fertility clinic in New York. Dr. Radjabi says he and his colleagues have developed a two-step process to be offered alongside the clinic's more traditional I.V.F. services. First, with blood samples from the parents, he will tell them what possible eye colors they might produce. That screening will cost $1,200. Second, assuming the necessary variety is present, he'll reveal which of the available eggs contain a high likelihood of which eye color. That part will be $12,500. What the parents choose next, he assured me repeatedly, is not for him to decide. But the implication was clear. "We had a couple where she had wonderful blue eyes, and he, with dark eyes, said 'If we have embryos that have blue eyes I'd love to know,'"

Dr. Radjabi recalls. "Most everybody wants blue or green eye color." He says his clinic is currently overwhelmed with demand for the procedure, with more than 200 people signed up for the process.

Dr. Radjabi's offering is part of a broader field known as pre-implantation genetic diagnosis, or P.G.D., that is almost entirely unregulated. And in 2009, The Wall Street Journal reported that Dr. Radjabi's business partner, Dr. Jeffrey Steinberg of the Fertility Institutes in Los Angeles, had promised his I.V.F. customers the chance to make "a preselected choice of gender, eye color, hair color and complexion, along with screening for potentially lethal diseases." Steinberg's site no longer offers the chance to choose your kid's skin color, but gender selection is prominently advertised.

Those products are built on well-understood genetic mechanisms. But if we each begin receiving polygenic scores for social and behavioral traits, what will the moneymaking world do with that? John Hancock, one of the nation's oldest insurers, recently announced it's going to write discounted policies for people who wear devices that track their health and fitness. The 2008 Genetic Information Nondiscrimination Act, or GINA, makes it illegal for insurance companies to discriminate on the basis of your genes, but it might be that group-level predictions, like the ones that polygenic scores make possible, form a loophole in both GINA and the pre-existing condition protections of the Affordable Care Act. Technology simply moves faster than regulations can.

And will the preselection opportunities of I.V.F. make it an irresistible means of creating the best possible child, the only choice of responsible parents? Who am I to deny my kids any conceivable advantage, no matter how statistically insignificant? If DNA can tell me and my wife which of her embryos has the highest polygenic score, we won't care whether the improvement is 10 percent or 5 percent or 1 percent. That kid will have a better chance at success. *Doctor, we've talked it over. We'll take that one.*

Science has to be slow if it's going to merit the name: Do the research, compile the findings, publish it, wait for others to attempt the same thing, wait longer still to learn whether they found what you found. But business is fast. And as it becomes steadily faster, it seizes on incremental, unreplicated scientific findings and builds products, brands, whole industries out of them, before anything approaching a scientific truth can be established, and long before society can hash out its implications.

The geno-economists seem confident that human genes have a measurable influence on human outcomes. But publicizing whatever predictive power does lie in our genes runs the risk of misleading the rest of us into believing that control of our genes is control of our future. They're adamant that their motives are in forestalling the dystopian implications of the work, in fighting off misinformation and misguided policies. "The world in which we can predict all sorts of things about the future based on saliva samples — personality traits, cognitive abilities, life outcomes — is happening in the next five years," Benjamin says. "Now is the time to prepare for that."

Even so, the researchers themselves acknowledge that it's hard to think about oneself clearly when subjected to this new tool. Benjamin, Conley and several others in the study went ahead and got their own polygenic scores measured. It was for fun, mostly, and no one was unhappy with their results. "But at the moment I did it, I regretted doing it," Conley says. "It's a cognitive trap. I immediately realized that at an individual level, it doesn't predict anything, but it's human nature to want to know more about yourself. I don't know …" He pauses for several seconds. "People parse meaningless distinctions."

Benjamin is less conflicted. "I don't regret doing it," he says. "But I'm an economist, so I'm trained to always think more information is better."

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FROM GENE EDITING TO A.I., HOW WILL TECHNOLOGY TRANSFORM HUMANITY?

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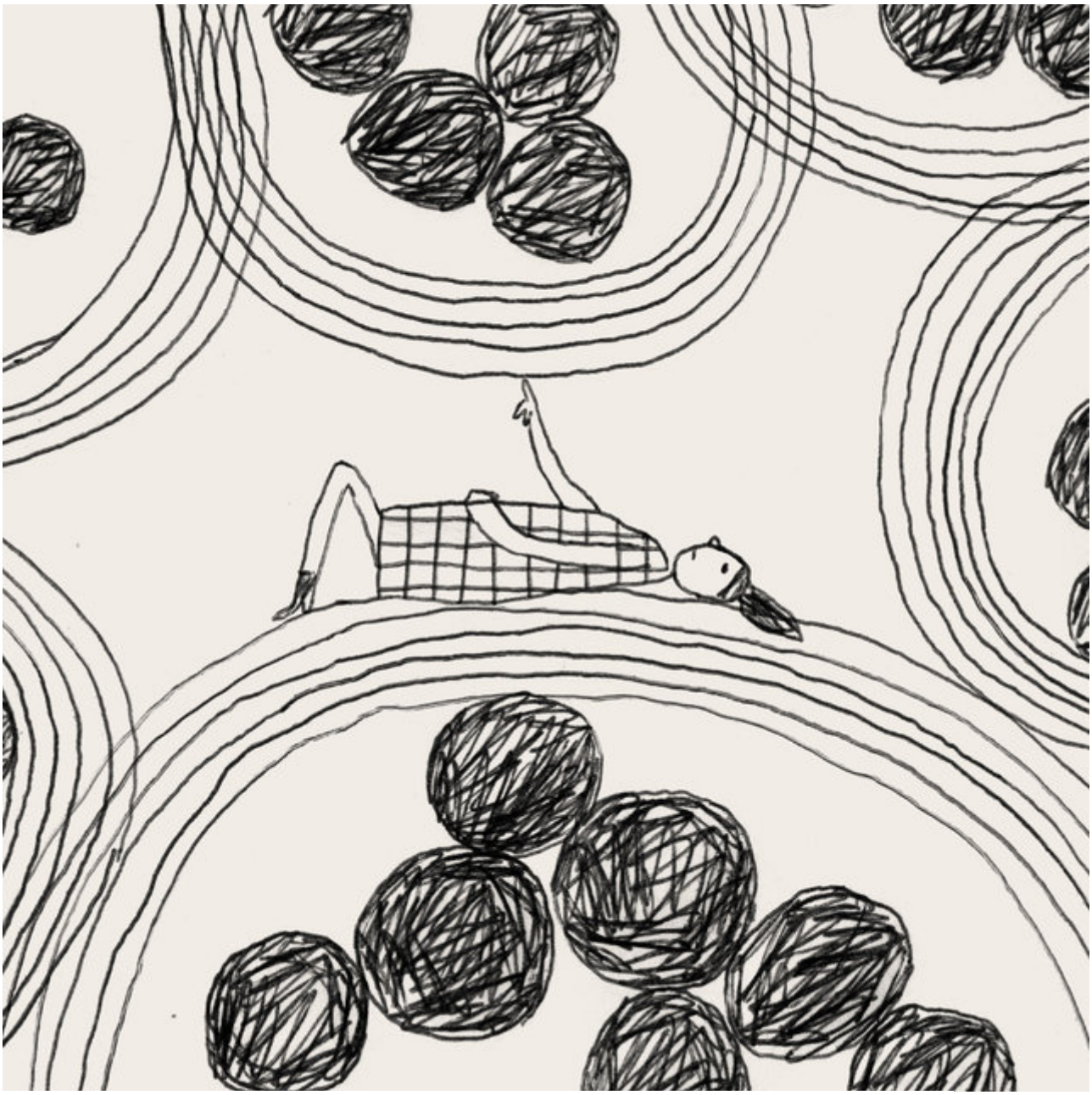

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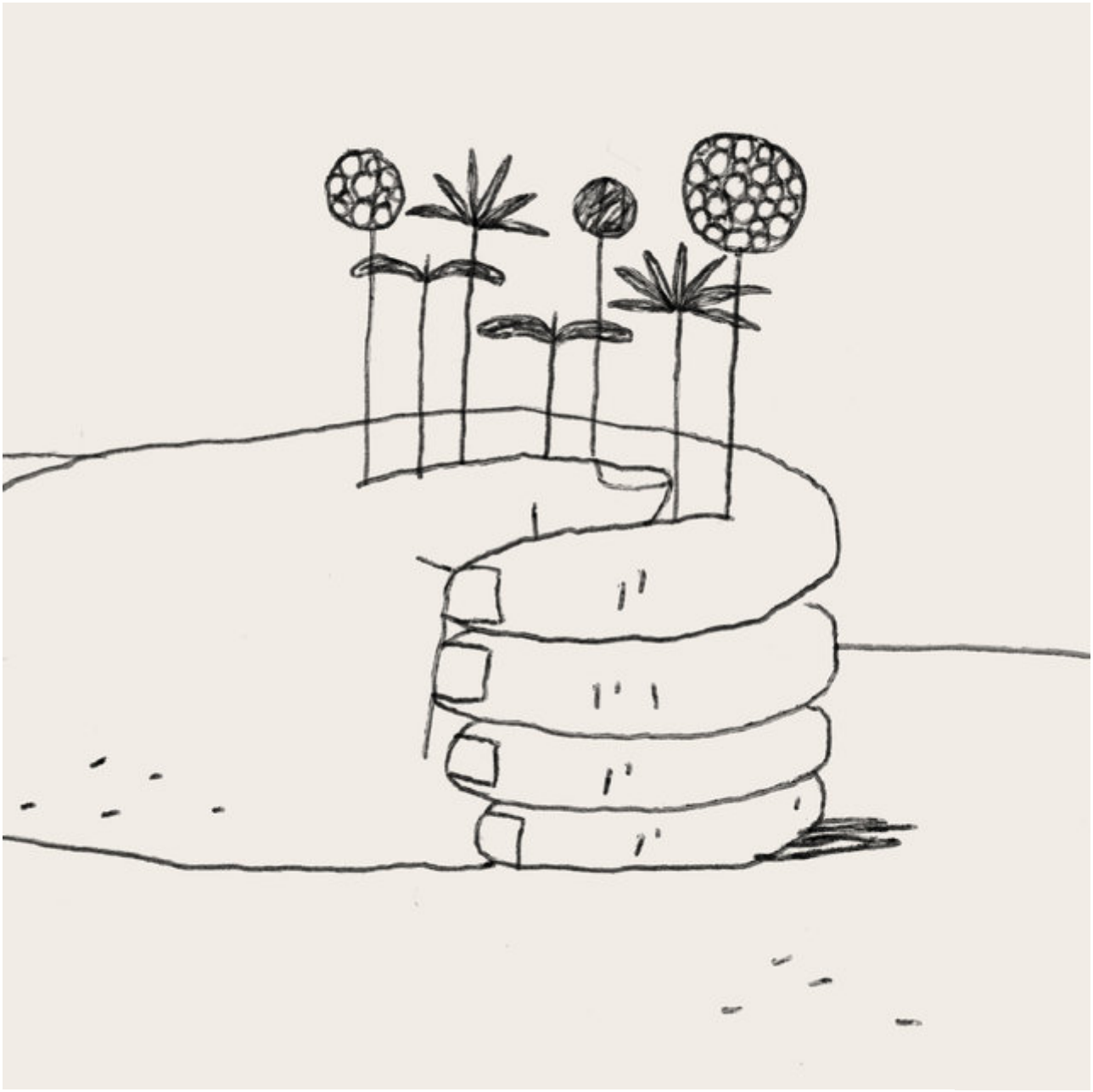

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