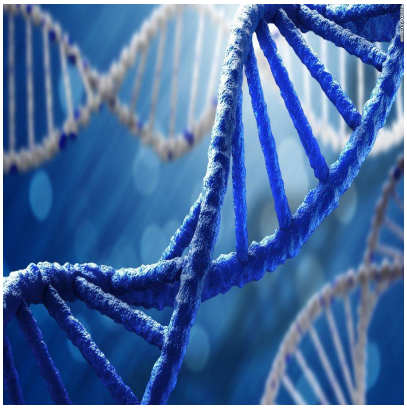

Your DNA Can Now Be Pulled Out Of Thin Air

Description

DNA is the foundation of life and is found throughout the environment. Because of shedding, humans leave a continuous trail of DNA that can be measured and sequenced. Genetic scientists have now discovered how to easily sequence environmental DNA, called E-DNA. The implications to privacy and sanctuary are absolutely staggering and police/intelligence units are salivating to get their hands on it.? TN Editor

David Duffy, a wildlife geneticist at the University of Florida, just wanted a better way to track disease in sea turtles. Then he started finding human DNA everywhere he looked.

Over the last decade, wildlife researchers have refined techniques for recovering environmental DNA, or eDNA — trace amounts of genetic material that all living things leave behind. A powerful and inexpensive tool for ecologists, eDNA is all over — floating in the air, or lingering in water, snow, honey and even your cup of tea. Researchers have used the method to detect invasive species before they take over, to track vulnerable or secretive wildlife populations and even to rediscover species thought to be extinct. The eDNA technology is also used in wastewater surveillance systems to monitor Covid and other pathogens.

But all along, scientists using eDNA were quietly recovering gobs and gobs of human DNA. To them, it’s pollution, a sort of human genomic bycatch muddying their data. But what if someone set out to collect human eDNA on purpose?

New DNA collecting techniques are “like catnip” for law enforcement officials, says Erin Murphy, a law professor at the New York University School of Law who specializes in the use of new technologies in the criminal legal system. The police have been quick to embrace unproven tools, like using DNA to create probability-based sketches of a suspect.

That could pose dilemmas for the preservation of privacy and civil liberties, especially as technological advancement allows more information to be gathered from ever smaller eDNA samples. Dr. Duffy and his colleagues used a readily available and affordable technology to see how much information they could glean from human DNA gathered from the environment in a variety of circumstances, such as

from outdoor waterways and the air inside a building.

The results of their research, published Monday in the journal Nature Ecology & Evolution, demonstrate that scientists can recover medical and ancestry information from minute fragments of human DNA lingering in the environment.

Forensic ethicists and legal scholars say the Florida team's findings increase the urgency for comprehensive genetic privacy regulations. For researchers, it also highlights an imbalance in rules around such techniques in the United States — that it's easier for law enforcement officials to deploy a half-baked new technology than it is for scientific researchers to get approval for studies to confirm that the system even works.

Genetic trash to genetic treasure

It has been clear for decades that fragments of our DNA cover the planet like litter. It just didn't seem to matter. Scientists believed DNA in the environment was too small and too degraded to be meaningfully recovered, much less used to identify an individual human being, unless it came from distinct samples like a bloodstain or an object someone had touched.

Wildlife researchers embraced environmental DNA anyway because they're only looking for very small segments of DNA — scanning for what they call bar codes that will identify the creatures in a sample to a species level. But after finding "surprising" levels of human eDNA in their samples while monitoring disease in Florida sea turtles, Dr. Duffy and his team set out to get a more accurate picture of the condition of human DNA in the environment, and to see how much information it could reveal about people in an area.

As a proof of concept in one of their experiments, the researchers scooped up a soda-can-size sample of water from a creek in St. Augustine, Fla. They then fed the genetic material from the sample through a nanopore sequencer, which allows researchers to read longer stretches of DNA. The one they used cost about $1000, is the size of a cigarette lighter and plugs into a laptop like a flash drive.

From the samples, the team recovered much more legible human DNA than they had anticipated. And as knowledge expands about human genetics, analysis of even limited samples can reveal a wealth of information.

The researchers recovered enough mitochondrial DNA — passed directly from mother to child for thousands of generations — to generate a snapshot of the genetic ancestry of the population around the creek, which roughly aligns with the racial makeup reported in the latest census data for the area (although the researchers note that racial identity is a poor proxy for genetic ancestry). One mitochondrial sample was even complete enough to meet the requirements for the federal missing persons database.

They also found key mutations shown to carry a higher risk of diabetes, cardiac issues or several eye diseases. According to their data, someone whose genetic material turned up in the sample had a mutation that could lead to a rare disease that causes progressive neurological impairment and is often fatal. The illness is hereditary and may not emerge until a patient's 40s. Dr. Duffy couldn't help but wonder — does that person know? Does the person's family? Does the person's insurance company?

Surveillance and forensics

Anna Lewis, a Harvard researcher who studies the ethical, legal and social implications of genetics research, said that environmental DNA hadn't been widely discussed by experts in bioethics. But after the findings from Dr. Duffy and his colleagues, it will be.

Technology focused on eDNA, she said, could be used for surveillance of certain kinds of people — for example, people with a specific ancestral background or with particular medical conditions or disabilities.

The implications of such uses, researchers agree, depend on who is using the technology and why. While pooled eDNA samples could help public health researchers determine the incidence of a mutation that causes a disease in a community, that same eDNA sample could equally be used to find and persecute ethnic minorities.

"This gives a powerful new tool to authorities," Dr. Lewis said. "There's internationally plenty of reason, I think, to be concerned." Countries like China already conduct extensive and explicit genetic tracking of minority populations, including Tibetans and Uighurs. Tools like eDNA analysis could make it that much easier, she said.

How much of an ethical minefield eDNA research will be also depends on the extent to which it's possible to identify an individual. In some situations, it's already achievable.

The kind of genetic data Dr. Duffy recovered from public places wouldn't work with the methods law enforcement personnel in the United States currently use to identify individuals, said Robert O'Brien, a forensic biologist at Florida International University and a former crime laboratory DNA analyst.

When law enforcement DNA analysts compare a crime scene sample to a suspect, they're looking at 20 markers spread across the human genome that are tracked by the F.B.I.'s Combined DNA Index System, or CODIS, Mr. O'Brien said. Those markers are only useful if there's certainty that several of them come from the same person, and because the eDNA fragments Dr. Duffy studied can't capture more than one marker at a time, a public place like the Florida stream becomes a nightmarish jigsaw puzzle.

However, forensic researchers suggest that individual identification from eDNA could already be possible in enclosed spaces where fewer people have been. Last October, a team from the Oslo University Hospital's forensic research center piloted a new technique to recover human DNA from air samples and was able to construct full CODIS profiles from airborne DNA inside an office.

That highlights the possibility that law enforcement officials could use eDNA collected at crime scenes to incriminate people, even though wildlife ecologists who developed the techniques say the science

isn’t mature enough for such purposes. Scientists have yet to pin down the fundamentals of eDNA, like how it travels through air or water or how it degrades over time. And nanopore sequencing — the technology that allowed Dr. Duffy’s team to find longer and more informative DNA fragments — still has a much higher error rate than older technologies, meaning an unusual genetic signature that seems like a promising lead could be a red herring.

Who gets access when DNA is free for the taking?
In the United States, rules vary widely for who is allowed to capture and analyze DNA.

University scientists hoping to learn more about human eDNA must justify the scope and privacy concerns of their studies in an imperfect process involving ethics boards at their institutions that can limit or reject experiments. But there are no such guardrails for law enforcement officials trying out a new technology.

“There’s an imbalance in almost all systems of the world between what law enforcement is allowed to do, versus publicly funded research, versus private companies,” said Barbara Prainsack, a professor at the University of Vienna who studies the regulation of DNA technology in medicine and forensics.

While some countries, like Germany, have an approved green list of technologies and forms of evidence that law enforcement agencies can use, it’s exactly the reverse in the United States.

“It’s a total wild west, a free for all,” said Ms. Murphy, the N.Y.U. law professor. “The understanding is police can sort of do whatever they want unless it’s explicitly prohibited.”

Often, the public and other branches of government learn that law enforcement officials have adopted a new technique only at a news conference announcing an arrest, Ms. Murphy said. She pointed specifically to the arrest of the Joseph James DeAngelo, the Golden State Killer, which the police credited to the use of genetic genealogy — entering crime scene DNA into family history databases and triangulating a criminal’s identity based on distant cousins. In those high-profile cases, she said, law enforcement personnel rely “on the good will they engender when they do use the technology for really positive uses.” Other uses might not be disclosed.

Safeguards against misusing a new technology like eDNA rely on the courts, where experts say the track record is poor.

To keep immature or bunk science out of legal deliberations, trial judges are supposed to determine whether an expert’s scientific testimony “rests on a reliable foundation.” Ms. Murphy said it was unreasonable to expect every trial judge to keep abreast of the latest scientific advancements. The rules of evidence, she added, “favor the admission of evidence and expect the jury to sort out what to believe and what not to believe.”

For decades, organizations like the Innocence Project have worked to weed pseudoscience out of courts — microscopic hair analysis, blood spatter analysis and bite mark evidence have all been used to wrongly convict defendants. Even in the face of overwhelming evidence that those technologies aren’t reliable, “courts are still reluctant not to allow it or to overturn a case” based on such lines of evidence because of the long precedent of their use, said Aliza Kaplan, a professor at Lewis & Clark Law School in Portland, Ore., and counsel to the Forensic Justice Project.

The Fourth Amendment's prohibition of "unreasonable search and seizure" without probable cause is also supposed to prevent the erosion of privacy by a powerful new technology. However, since the early 2000s, many prosecutors and courts have taken the stance that any DNA not still attached to a person has been abandoned, meaning that the police don't need a warrant to collect it.

But it may be almost impossible to avoid leaving DNA in public. Dr. Duffy and his colleagues found that they could successfully collect airborne human DNA even from people wearing gloves and surgical masks and gowns.

"That really belies the idea that we are in any way voluntarily shedding our genetic material," said Vera Eidelman, a staff attorney at the American Civil Liberties Union who focuses on constitutional claims regarding genetic privacy and who was not involved in the Florida team's study.

Consent and genetic exceptionalism
It's possible to compare human eDNA sampling to other surveillance technologies members of the public don't individually consent to, like facial recognition cameras. But experts say there's an important distinction.

When it comes to collecting DNA, individuals aren't the only ones affected. It also implicates "family members and, in some contexts, communities," said Sandra Soo-Jin Lee, a biomedical ethicist at Columbia University.

"DNA tracks to your extended relatives, tracks forward in time to your children, tracks backward in time to your ancestors," Ms. Murphy added. "In the future, who knows what DNA will tell us about people or how it might be used?"

There's a wide market for genetic information — from pharmaceutical companies developing therapeutics, to insurance actuaries, to public health researchers. But protections for the public are stymied by the lack of workable legal definitions of what DNA actually is. Is it personal property, Ms. Murphy asks? Is it data? Is it always medical information? Who owns it once it has been collected?

Bioethicists and civil liberties experts say that Dr. Duffy's warning provides decision makers a rare chance to discuss the ethics and the legality of a new genetic technique before it enters widespread use. Usually, they're playing catch-up — but thanks to wildlife ecologists, now they have a modest head start.

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