When The DNA You Carry Is Not Yours!

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Society has humanly reasoned ways of "solving" health problems, ways that seem right to it. Often, they have unexpected consequences. In the case of genetic modification (GMOs), the negative consequences are numerous. However, even when there is not direct manipulation, there are indirect human interferences that can affect our DNA.

In a December 7, 2019, *New York Times* article titled, "When a DNA Test Says You're a Younger Man, Who Lives 5,000 Miles Away," Heather Murphy tells the story of a man with leukemia who, after a bone marrow transplant, found that his donor's DNA traveled to unexpected parts of his body. A crime lab is now studying the case.

> Three months after his bone marrow transplant, Chris Long of Reno, Nevada, learned that the DNA in his blood had changed. It had all been replaced by the DNA of his donor, a German man he had exchanged just a handful of messages with.
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> He'd been encouraged to test his blood by his colleague Ms. Romero at the Sheriff's Office, where he worked. She had an inkling this might happen. It's the goal of the procedure, after all: Weak blood is replaced by healthy blood, and with it, the DNA it contains.
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> But four years after his lifesaving procedure, it was not only Mr. Long's blood that was affected. Swabs of his lips and cheeks contained his DNA—but also that of his donor.
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> Tens of thousands of people get bone marrow transplants every year, for blood cancers and other blood diseases including leukemia, lymphoma and sickle cell anemia. Though it's unlikely that any of them would end up as the perpetrator or victim of a crime, the idea that they could intrigued Mr. Long's colleagues at the Washoe County Sheriff's Department.

So, Chris Long agreed to serve as a guinea pig for his colleagues' experiment to help them understand how a bone marrow transplant could confuse a criminal investigation. This may not be of concern to the average doctor, but for a forensic scientist, it's a different story. The assumption among criminal investigators as they gather DNA evidence from a crime scene is that each victim and each perpetrator leaves behind a single identifying code—not two, such as that of a fellow who is 10 years younger and lives thousands of miles away.

Four years later, with Mr. Long in remission and back at work, Ms. Romero's experiment persisted, aided by her crime lab colleagues. Within four months of the procedure, Mr. Long's blood had been replaced by his donor's blood. Swabs collected from his lip, cheek and tongue showed that these also contained his donor's DNA, with the percentages rising and falling over the years.

Of the samples collected, only his chest and head hair were unaffected. The most unexpected part was that four years after the procedure, the DNA in his semen had been entirely replaced by his donor's.

> "We were kind of shocked that Chris was no longer present at all," said Darby Stienmetz, a criminalist at the Washoe County Sheriff's Office. "I thought that it was pretty incredible that I can disappear and someone else can appear," Mr. Long said.

Mr. Long had become a chimera, the technical term for the rare person with two sets of DNA.

What Are Chimeras? "Chimeras" are animals or humans that contain the cells of two or more individuals. Their bodies contain two different sets of DNA with the code to make two separate organisms. The condition is believed to be quite rare. It could be becoming more common with certain fertility treatments like in vitro fertilization, but this isn't proven.

Only about 100 or so cases of chimerism have been recorded in modern medical literature. Often, it causes two distinct types of colorings on different halves of the same animal, such as two different-colored eyes.

Human and animal chimeras can have two different blood types at the same time. It may be similar amounts of each blood type. For example, in one case, a female chimera had blood that was 61 percent type O and 39 percent type A. But it's possible for it to happen elsewhere in the body.

People may experience one of several types of chimerism. Each has a slightly different cause and may result in different symptoms. In humans, chimerism most commonly occurs when a pregnant woman absorbs a few cells from her fetus. The opposite may also happen, where a fetus absorbs a few cells from its mother.

These cells may travel into the mother's or fetus's bloodstream and migrate to different organs. They may remain in a mother's body or a child's body for a decade or more following childbirth. This condition is called microchimerism.

In one study, researchers tested tissue samples from the kidneys, livers, spleens, lungs, hearts, and brains of 26 women who tragically died while pregnant or within one month of giving birth. The study found that the women had fetal cells in all of these tissues. The cells were from the fetus, and not from the mother, because the cells contained a Y chromosome (found only in males) and the women had all been carrying sons. Experts are not sure exactly what effects this chimerism has on the mother and child.

In some cases, fetal cells may stay in a woman's body for years. In a 2012 study, researchers analyzed the brains of 59 women, ages 32 to 101, after they had died. They found 63% of these women had traces of male DNA from fetal cells in their brains. The oldest woman to have fetal cells in her brain was 94 years old, suggesting that these cells can sometimes stay in the body for a lifetime.

A similar kind of chimerism can occur when a person receives a blood transfusion, stem cell transplant, or bone marrow transplant from another person and absorbs some of that person's cells. This is because bone marrow continues to regenerate. This is called artificial chimerism. Artificial chimerism was more common in the past. Today, transfused blood is usually treated with radiation. This helps the transfusion or transplant recipient better absorb the new cells without permanently incorporating them into their body.

In 2004, investigators in Alaska uploaded a DNA profile extracted from semen to a criminal DNA database. It matched a potential suspect, but there was a problem: The man had been in prison at the time of the assault. It turned out that he had received a bone marrow transplant. The donor, his brother, was eventually convicted. (Not a very nice family!)

Another way that chimeras can occur is when a pair of twins is conceived and one embryo dies in the womb. The surviving fetus may absorb some of the cells of its deceased twin. This gives the surviving fetus two sets of cells: its own, and some of its twin's. Twin chimeras may experience an increased rate of autoimmune disease.

Fraternal twin chimeras can create confusing scenarios when they acquire each other's DNA in the womb. In at least one case, that led to unfounded fears of infidelity when a man's child did not seem to be his. In another case, a mother nearly lost custody of her children after a DNA test.

Recently, a singer from California named Ms. Muhl was profiled as a chimera. She reports that she has twin chimerism, meaning she absorbed some of her twin's cells while she was in her mother's womb. This has left her with a half-white, half-reddish pigmentation on the skin covering her abdomen.

In another recent story, a male chimera failed a paternity test because the DNA his child inherited came from the twin he absorbed in the womb.

The symptoms of chimerism vary from person to person. Many with this condition show no signs, or they may not recognize these signs as chimerism. Some symptoms include:

- hyperpigmentation (increased skin darkness) or hypopigmentation (increased skin lightness) in small patches or across areas as large as half of the body
- two different-colored eyes
- genitals that have both male and female parts (intersex), or that look sexually unclear (this sometimes results in infertility)
- two or more sets of DNA present in the body's red blood cells
- possible autoimmune issues, such as those related to the skin and nervous system

Chimeras are one of those curious possibilities that forensic analysts now have to consider when DNA results are not adding up.

Genetic tests can help uncover whether a person's blood cells contain DNA that's not present in the rest of their bodies. Multiple sets of DNA in the bloodstream are a classic sign of chimerism. There's no way to eliminate a person's chimerism. But people may go their entire life without knowing they are chimeras because the condition is rare and people aren't usually tested for it, or the symptoms may not even show up.