The big idea
Genetics

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The big idea: can you inherit memories from your ancestors?

The science of epigenetics suggests we can pass on trauma – but trust and compassion too

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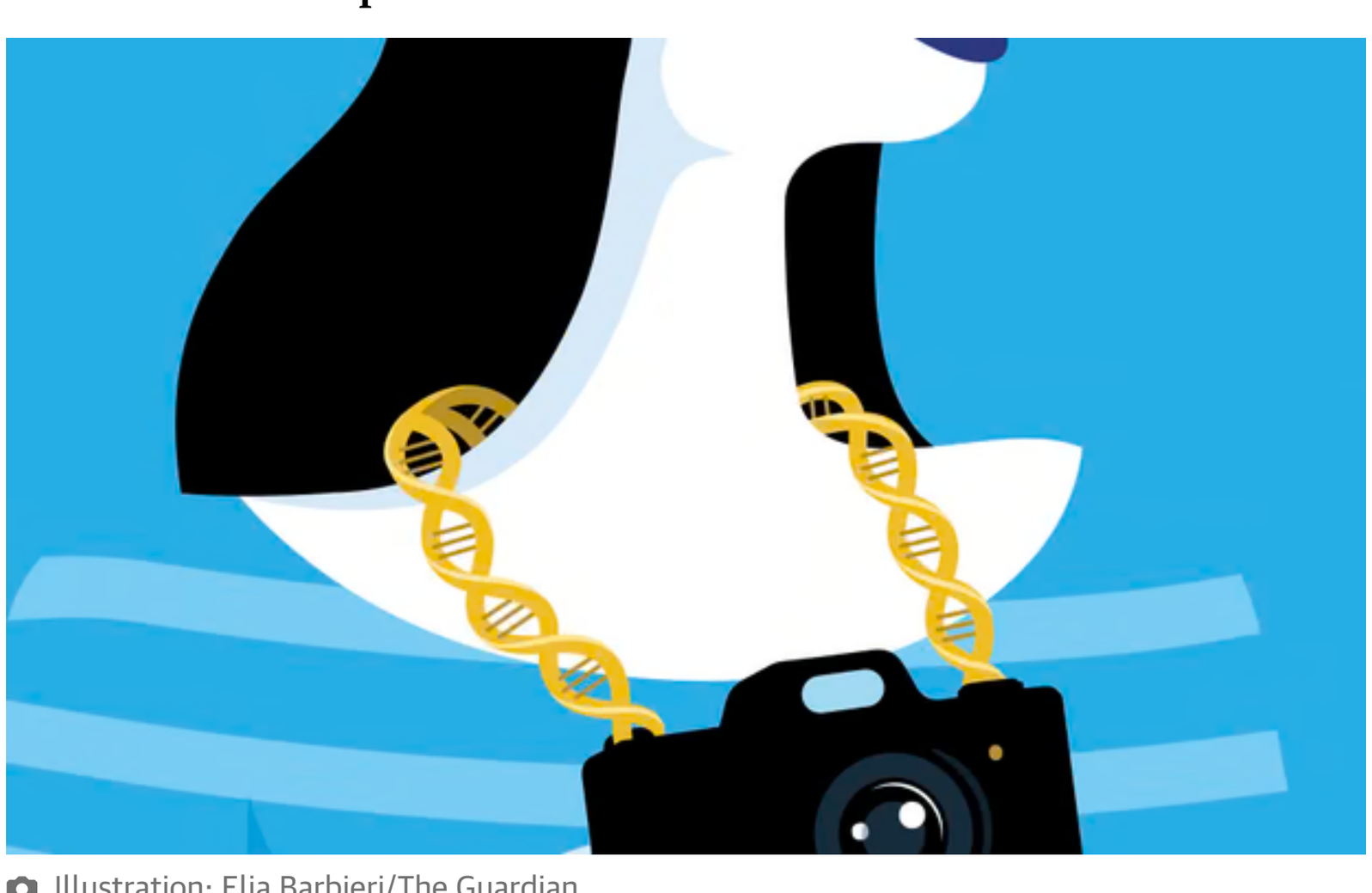

Illustration: Elia Barbieri/The Guardian

Since the sequencing of the human genome in 2003, genetics has become one of the key frameworks for how we all think about ourselves. From fretting about our health to debating how schools can accommodate non-neurotypical pupils, we reach for the idea that genes deliver answers to intimate questions about people's outcomes and identities.

Recent research backs this up, showing that complex traits such as temperament, longevity, resilience to mental ill-health and even ideological leanings are all, to some extent, "hardwired". Environment matters too for these qualities, of course. Our education and life experiences interact with genetic factors to create a fantastically complex matrix of influence.

But what if the question of genetic inheritance were even more nuanced? What if the old polarised debate about the competing influences of nature and nurture was due a 21st-century upgrade?

Scientists working in the emerging field of epigenetics have discovered the mechanism that allows lived experience and acquired knowledge to be passed on within one generation, by altering the shape of a particular gene. This means that an individual's life experience doesn't die with them but endures in genetic form. The impact of the starvation your Dutch grandmother suffered during the second world war, for example, or the trauma inflicted on your grandfather when he fled his home as a refugee, might go on to shape your parents' brains, their behaviours and eventually yours.

Much of the early epigenetic work was performed in model organisms, including mice. My favourite study is one that left the neuroscience community reeling when it was published in Nature Neuroscience, in 2014. Carried out by Prof Kerry Ressler at Emory University, Georgia, the study's findings neatly dissect the way in which a person's behaviours are affected by ancestral experience.

The study made use of mice's love of cherries. Typically, when a waft of sweet cherry scent reaches a mouse's nose, a signal is sent to the nucleus accumbens, causing this pleasure zone to light up and motivate the mouse to scurry around in search of the treat. The scientists exposed a group of mice first to a cherry-like smell and then immediately to a mild electric shock. The mice quickly learned to freeze in anticipation every time they smelled cherries. They had pups, and their pups were left to lead happy lives without electric shocks, though with no access to cherries. The pups grew up and had offspring of their own.

At this point, the scientists took up the experiment again. Could the acquired association of a shock with the sweet smell possibly have been transmitted to the third generation? It had. The grandpups were highly fearful of and more sensitive to the smell of cherries. How had this happened? The team discovered that the DNA in the grandfather mouse's sperm had changed shape. This in turn changed the way the neuronal circuit was laid down in his pups and their pups, rerouting some nerve cells from the nose away from the pleasure and reward circuits and connecting them to the amygdala, which is involved in fear. The gene for this olfactory receptor had been demethylated (chemically tagged), so that the circuits for detecting it were enhanced. Through a combination of these changes, the traumatic memories cascaded across generations to ensure the pups would acquire the hard-won wisdom that cherries might smell delicious, but were bad news.

The study's authors wanted to rule out the possibility that learning by imitation might have played a part. So they took some of the mice's descendants and fostered them out. They also took the sperm from the original traumatised mice, used IVF to conceive more pups and raised them away from their biological parents. The fostered pups and those that had been conceived via IVF *still* had increased sensitivity and different neural circuitry for the perception of that particular scent. Just to clinch things, pups of mice that had not experienced the traumatic linking of cherries with shocks did not show these changes even if they were fostered by parents who had.

The most exciting thing of all occurred when the researchers set out to investigate whether this effect could be reversed so that the mice could heal and other descendants be spared this biological trauma. They took the grandparents and re-exposed them to the smell, this time without any accompanying shocks. After a certain amount of repetition of the pain-free experience, the mice stopped being afraid of the smell. Anatomically, their neural circuits reverted to their original format. Crucially, the traumatic memory was no longer passed on in the behaviour and brain structure of new generations.

Could the same thing hold true for humans? Studies on Holocaust survivors and their children carried out in 2020 by Prof Rachel Yehuda at the Icahn School of Medicine at Mount Sinai Medical School, New York, revealed that the effects of parental trauma can indeed be passed on in this way. Her first study showed that participants carried changes to a gene linked to levels of cortisol, which is involved in the stress response. In 2021, Yehuda and her team carried out more work to find expression changes in genes linked to immune-system function. These changes weaken the barrier of white blood cells, which allows the immune system to get improperly involved in the central nervous system. This interference has been linked to depression, anxiety, psychosis and autism. Since then, Ressler and Yehuda have collaborated, with others, to reveal epigenetic tags in PTSD afflicted war zone-exposed combatants. They are hoping this information could aid PTSD diagnosis or even pre-emptively screen for individuals who might be more prone to developing the condition before they enter the battlefield.

In all times and across all cultures, people have paid their dues to their ancestors and pondered the legacy they will leave for their descendants. Few of us believe any more that biology is necessarily destiny or that our bloodline determines who we are. And yet, the more we learn about how our body and mind work together to shape our experience, the more we can see that our life story is woven into our biology. It's not just our body that keeps the score but our very genes.

Might this new understanding increase our capacity for self-awareness and empathy? If we can grasp the potential impact of our ancestors' experiences on our own behaviour, might we be more understanding of others, who are also carrying the inherited weight of experience?

We are, as far as we know, the only animals capable of "cathedral thinking", working on projects over many generations for the benefit of those who come after. It's an idealistic way to think about legacy, but without it we will struggle to tackle complex multigenerational challenges such as the climate and ecological emergencies. Our knowledge of epigenetics and its potential to massively speed up evolutionary adaptation could support us to do everything we can to be the ancestors our descendants need. Conflict, neglect and trauma induce unpredictable and far-reaching changes. But so do trust, curiosity and compassion. Doing the right thing today could indeed cascade across generations.

- Dr Hannah Critchlow is a neuroscientist and author of The Science of Fate and Joined-Up Thinking (Hodder).

Further reading

The Epigenetics Revolution: How Modern Biology is Rewriting Our Understanding of Genetics, Disease and Inheritance by Nessa Carey (Icon, £11.99)

Genome: The Autobiography of Species in 23 Chapters by Matt Ridley (4th Estate, £10.99)

Blueprint: How Our Childhood MadeMakes Us Who We *Are* by Lucy Maddox (Robinson, £10.99)

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