

Susan Greenfield: The interaction between genes and environment Keywords: brain; gene; environment

(courtesy of Andrea Tappe)

Many have alluded to the importance of the environment on the developing brain. As a neuroscientist, I root and endorse that view in the bump and grind of brain cells. You are born with most of the brain cells you will ever have. It is the growth of the connections between the brain cells that accounts for the growth of the brain after birth. What is exciting is that the environment will influence the configuration of those connections. So even if you are a clone-that is, 5 an identical twin-you will have a unique pattern of brain cell connections.

Genes play a part. I do not wish to denigrate genes; I merely wish to put them, despite all the hype, literally in their place. Genes make proteins, which are important biochemical baggage for brain cell circuits to work. But they are not a one-off, they are constantly being activated or switched off according to the caprices of the environment, whether it is the micro-milieu of the brain itself or the external environment in which you are moving.

10 Hence you will appreciate that it is impossible to make the old and hackneyed division between [nature and nurture](#). Rather we should think of a dialogue, an interaction, where there is no genetic controller orchestrating events but a ceaseless interaction between the environment and the molecular landscape of the brain. What is important is that the environment can determine how that landscape looks.

Let me take, for example, what may seem to be a counter-example. The condition Huntington's chorea-named after the 15 Greek for "to dance"-is so-called because it is characterised by a wild involuntary flinging of the limbs in a grotesque form of dance. The reason for choosing this example is that it is one of the few brain disorders that can be attributed to a single rogue gene. However, we know that even in mice that have had their genes tweaked so that they have the single rogue gene - they have the mouse equivalent of this movement disorder-the onset and severity of the disease can be offset. It can be made much more moderate and come along much later in their lives if they have a so-called 20 enriched environment. For a mouse this means a few little ladders and toys with which they interact.

We know that adult rats exposed to ladders and toys and a so-called enriched environment will have more connections in their brains. The brain cells have more branches, which enable the brain cells to form more connections than their counterparts kept in simpler conditions. If this is the case for adult rodents playing with a few little ladders and wheels, how much more for the human brain?

25 The most marvellous aspect of being born a human being is that you are freed-up more than any other animal from the tyranny of your genes; you are freed-up from having to obey instinct. That is why we, as a species, occupy more ecological niches than any other species on earth. It is because we are supremely able, compared to any other species, to learn that we are freed-up from the demands of instinct. And if you have individual experiences, guess what? You become an individual.

30 We are born into the world, in the words of the nineteenth century psychologist William James, "as a booming, buzzing confusion". We evaluate it in terms of its primary sensory qualities-how sweet, how fast, how cold, how bright-but gradually these abstract sensations will coalesce into faces and objects. Gradually, as we get language, those faces and objects will acquire a name, a label. If they SK mean something to us they will feature in certain events in our lives that become memories. The more they feature, the more connections they will trigger and the more deep their significance 35 to us will become.

As this happens, we personalise our brains; we develop a mind. It is this learning, this ability to see one thing in terms of another, that I regard as understanding. Far from being some airy-fairy alternative to the squalor of the physical brain, I see the mind as the personalisation of the brain. It is these personalised connections, sadly, which can be dismantled by conditions such as Alzheimer's disease. As you may know, in such degenerative conditions the patient 40 will gradually recapitulate childhood; gradually the world will mean less and less and gradually the patient will retreat back into the booming and buzzing confusion, where even people and objects that were very dear and close to the patient are no longer recognised.

The point I am trying to make is that the competence of our brains, of our mental abilities, rests on the integrity and the extent and number of our brain connections. It is these connections, which, in turn, are dependent on the experiences 45 we have in the world.

You may have heard of a fascinating study recently undertaken with London taxi drivers. It is of course well known that London black-cab drivers learn the "knowledge"; they have to remember all the streets of London in order to navigate about without using references. This is a huge burden on that particular ability, but it turns out that the brain scans of London taxi drivers, when compared with people of like age, show an enhanced area related to memory. That 50 part of the brain is larger in taxi drivers than it is in other people. The fact is not lost on our London taxi drivers, most of whom have heard of the study. It is not the case that London taxi drivers are predisposed to having larger areas in this part of their brains. The longer someone works as a taxi driver, the more marked is the difference.

You do not have to be a London taxi driver to display plasticity in this way. It has been shown that non-piano players exposed for only five days to learning five-finger piano exercises will show an enhanced territory in the areas of their 55 brains related to the digits than will the so-called controls. More remarkable still is that those who were asked simply to imagine that they were playing the piano showed a similar structural change. I gather the same applies to golf. Apparently if you imagine that you are going to play golf and think about the golf swings, then when finally you go on to the course, you will find that you are more competent than would otherwise be the case.