Epigenetics: The soft side of evolutionary theory

By Dionne Shepherd

You've got to feel for a guy called Jean-Baptiste Lamarck. Although he was the first to develop a workable theory of evolution (around 1800, before the esteemed Charles Darwin was even born), he has been ridiculed by scientists for close on 150 years. The problem, it seems, was his suggested mechanism of evolution, dubbed "soft inheritance". Lamarck believed that characteristics acquired during an organism's lifetime can be inherited by its offspring. So, the oft-quoted theory goes, a giraffe acquired its long neck because it needed to stretch to reach leaves at the top of tall trees. This stretching elongated and strengthened the neck muscles, and slightly longer necks were inherited by the offspring. This is of course ridiculous. We all know that evolution of an organism occurs only gradually over many generations by the process of natural selection, right? Well, not entirely, no.

Recently the field of epigenetics has turned this idea of gradual change on its head. Modern Darwinism is the theory that evolutionary change comes about as a result of small genetic changes via mutation and recombination, fixed in a population by natural selection: this is a process that can take thousands of generations. Until very recently it was thought that heritable information, such as eye colour or that nervous tic you share with your grandmother, was carried only by our genes. This is known, in vindictive opposition to Lamarck's idea, as "hard inheritance". However, epigenetics has shown us that modifications in gene expression or activity can be inherited in one generation without any genetic change at all. Hence the term epi – "outside of" – genetics.

Epigenetics itself is not a new idea: researchers have known for some time that epigenetic regulation is important in embryo development. Even though the DNA sequence in all cells of a multicellular organism is the same, during embryogenesis cells differentiate into diverse cell types, for example those of the skin, brain or liver. This is achieved by activation of some genes and inhibition of others, and this pattern of gene expression is inherited during cell division, giving the cells a "memory". In other words, once the cell has been "told" it is a liver cell during embryo development, it remains a liver cell throughout the life of the organism. In addition, genomic imprinting is an epigenetic modification that causes one copy of a particular gene to be switched off, so that it's only inherited from one parent. This epigenetic regulation occurs by several mechanisms, the best-known of which is methylation. Methyl groups are hydrocarbon molecules with the formula CH_3: attachment of these groups to DNA modifies the DNA and alters its expression or activity, and this modification can be inherited through cell division.

So it turns out that the idea that a change in the environment can bring about a change in the behaviour of an organism that is then inherited by its offspring, is in fact not far off the mark. The field of epigenetics is still young, yet already there are numerous examples of heritable changes, brought on by the environment, that are independent of DNA sequence. The idea started to emerge from studies with mice: pregnant mothers fed a high-fat diet produced offspring prone to obesity and diabetes; these characteristics were even passed on to the second generation (the grandkids) even though the first-generation kids were never exposed to a high-fat diet. In another experiment that may vindicate Larmarck's ideas about soft inheritance, fruit flies that normally have white eyes were exposed as embryos to higher-than-normal temperatures. The flies that hatched had red eyes in response to the different environment; remarkably, even subsequent generations had partially-red eyes even though they were not themselves exposed to temperature changes - and this happened without any change in the flies' genes. Of significance for us, studies of human populations have highlighted the same thing. Extreme hunger experienced by pregnant mothers during wartime, for example, has been shown to affect the health of their grandchildren. Surprisingly, even extreme changes in the diets of men, for example starvation followed by a period of plenty, can significantly affect the longevity of their as-yet unconceived sons, and possibly even their grandsons, due to epigenetic changes brought on by the famine-feast period.

Of course, all this is not to say that Darwin was wrong; his theory is still up there among the best. What it may mean is that it's time for those hard hereditary theorists to soften up a bit. And finally give Lamarck a break.