of overlapping interests. Put them in a good physical plant with lots of shared space, and let them go to it. When it comes to the size of individual research groups, there's a value-for-money issue too — we are mostly spending the taxpayers' coin, after all. I have always had the impression that individual laboratory groups larger than about a dozen full-time workers produce less science per dollar spent than smaller groups.

We hear American academics talk about the balance between research and teaching. You're at a public university with tens of thousands of students — how do you view it? It is a tricky balance. Universities tend to reward research progress rather well and teaching success less so, at least in tangible career progress. But when you think about it, the range of activities that we carry out — doing research, training postgrads and postdocs, and teaching and advising undergraduates — is really a continuum. Research attracted most of us to this life, but in the public universities we also have an enormous, mandated public mission: to educate the students of our state, the nation and the world in science. And a great thing about being a science student in our research universities is that you are being taught mainly by active researchers: your neuroscience course is taught by a working neuroscientist, cell biology by a cell biologist, and so on. For part of the academic year I'm that guy, trying to make it seem worthwhile to hundreds of 19-year-olds to spend 15 weeks studying cell biology, trying to convey to them the excitement of this field. You can hardly fault academics who dodge a teaching assignment like that. Not everyone has the inclination or aptitude for teaching, and the incentive system can push you away from it. Still, if you take a pass on it, I think you're missing the boat. It's hard for a young assistant professor to believe, but your effect on students in the classroom will probably bring you closer to immortality than even your best paper. Our papers grow old and disappear, but, as Garrison Keillor says, "nothing you do for young people is ever wasted."

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My Word

Lysenko rising

Florian Maderspacher

When I recently unwrapped my weekly delivery of German magazine *Der Spiegel*, my fiancée thought she'd caught me ordering from the top shelf (she always had doubts about that particular magazine, despite my assurances that it is in fact one of Europe's largest news magazines). On the cover was a blond woman (it is German after all) rising from a computer-generated ocean. Around her naked breasts (it is European after all) the water was spiralling in the shape of a double helix. The headline read: "*The victory over the genes. Smarter, healthier, happier. How we can outwit our genome.*" Inside was a ten-page spread about epigenetics.

Epigenetics is of course being considered 'sexy' in vast circles of the scientific world (and has attracted the funding to go with it), but that *Spiegel* cover was a different type of 'sexy'. This kind of public attention seemed unusual: molecular biology rarely makes it to the front page. And what's more, this wasn't just some German oddity: *Newsweek* had last year a similar cover story, touting a revolution in biology in gonzo-journalism style: "*Roll over, Mendel. Watson and Crick? They are so your old man's version of DNA*". Likewise, the *New York Times* is in tune, as a news piece last year celebrated the role of the 'epigenome' in controlling "*which genes are on or off*"; nor is the hype confined to the popular press, as a recent editorial in *Nature* also noted that: "*genome sequences, within and across species, were too similar to be able to explain the diversity of life. It was instead clear that epigenetics — those changes to gene expression caused by chemical modification of DNA and its associated proteins — could explain much about how these similar genetic codes are expressed uniquely in different cells, in different environmental conditions and at different times*".

The term 'epigenetics' itself is fraught with misunderstandings (for an in-depth discussion, see an essay by Mark Ptashne, Curr. Biol. *17*, R233–R236). Initially coined by the geneticist C.H. Waddington as "*the branch of biology which studies the causal interactions between genes and their products which bring the phenotype into being*", the word epigenetics has undergone one of these curious shifts of meaning that characterise language evolution and are often the source of fundamental misunderstandings. Nowadays, as evident in the above quoted *Nature* editorial, 'epigenetics' is often used to flatly refer to chemical modifications of the DNA itself (methylation) or its associated protein scaffold, the histones.

'Victory over the genes': Cover of *Der Spiegel* on epigenetics. © 2010 DER SPIEGEL.

This was exactly the way epigenetics was used in the *Spiegel* piece: a graphic about 'switches in the genome' showed DNA methylation and histone modifications. A tiny blob in the bottom right corner symbolised a 'gene activating protein', otherwise there was no mention of signalling pathways or transcription factors in the entire article — the things that for half a century now have been known to be what brings 'the phenotype into being'. The article itself was mainly concerned with listing examples supporting the notion that 'genes aren't everything': on the one hand, cases where genetic predisposition, e.g. for adiposity, does not lead to the development of that phenotype, as well as the much-discussed weaknesses in genome-wide association studies to pick up causative genetic agents for common diseases; on the other hand, examples of how the environment can influence the genome, evident for instance as differences in DNA modifications between monozygotic twins in different environments and lifestyles. The piece culminated in bold statements like: "*Epigenetics is the long sought link through which the environment influences the hereditary material [… and it] currently leads to a dramatic new understanding of human biology*".

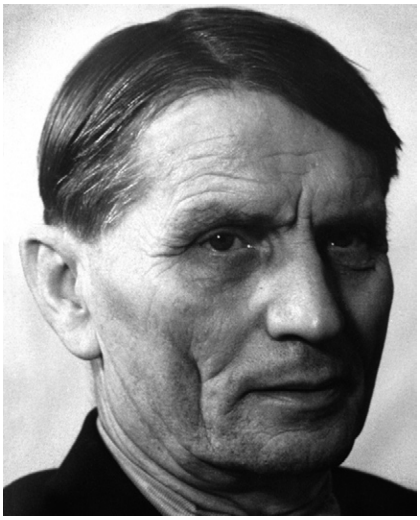
Somehow, the *Spiegel* piece struck a chord: judging from letters in response to the piece, part of the German readership received these 'news' with a kind of *schadenfreude* towards the science of genetics and its practitioners (slight echoes of a latent anti-scientific attitude in parts of the German public, here).

In a superficial sketch, the science behind all this goes something like this: DNA or DNA-associated histone proteins can become chemically modified. DNA itself becomes methylated, while histone proteins can be methylated, phosphorylated or acetylated. These chemical modifications are often associated with — but not necessarily instructing — changes in gene activity. In fact it is the other way around: the DNA sequence is instrumental in targeting the molecular machinery that makes the marks to the desired sites: epi-genetics, in that sense, comes 'after genetics'. That genes change their activity in response to intrinsic or extrinsic environmental conditions and cues is long and well known. Cells sense outside signals and respond by intracellular changes that involve ultimately a transcription factor activating (or repressing) the activity of a gene, namely its expression as mRNA. This concept is perfectly in line with the idea that it is the genes that determine how the phenotype is brought into being. In fact, environmentally regulated genes, such as Jacob and Monod's classic lac-operon or heat-induced genes in fruit flies, served as the first experimental systems in which the regulation of gene activity was studied.

In light of the above, there is no need to present the newly discovered 'epigenetic' marks as causing a paradigm shift in our understanding of how genes and inheritance work. It is all well-studied and consistent. The heretic appeal then lies in these marks being possible carriers of inheritance of acquired characters. This comes from the observation that at least DNA methylation marks, but as far as we know not histone modifications, can be maintained through cell divisions. But again, there is no indication that these marks *instruct* changes in gene activity. Indeed, there is little evidence that acquired traits can be inherited across generations. To be fair, there are some fascinating instances of heritable phenotypes, such as the transition between solitary and gregarious form in some locusts. But here, while the mechanisms are not fully understood, the alternative phenotypes and the transition between them are conventionally encoded in the locust genome and require no radical rethinking of genetics. There is thus no need to construe a dichotomy between the power of the genes and the power of the environment — a molecular version of the ancient nature vs. nurture debate. The environment influences the phenotype through the genes. There is no contrast, no one over whom to achieve 'victory'.

So, why all the fuss? Why the victorious girl rising from the ocean? It may well be that this topic resonates particularly well with Germans for historic reasons. After all, the idea that people's properties — good or bad — are determined by their heritage, and thus ultimately by genes, formed the centrepiece of Nazi ideology (though the Nazis preferred the term 'blood' over 'genes' when talking about hereditary factors). A certain degree of German gene-*angst* is thus perhaps understandable. But, as noted above, the hype about epigenetics is by no means confined to Germany.

Coarsely viewed, the contrast between nature (genetics) and nurture (epigenetics) mirrors the fault line of left vs. right in the political spectrum: the right believes that people are inherently good or bad, while the left believes in the power of the environment — loosely based on Marx's 'being determines consciousness', if you change the environment you better the person. While this is a worthwhile debate to be led in political terms, as soon as biology is invoked as a witness for either standpoint, the trouble usually begins.



Rising: Trofim Lysenko (1898–1976). Image: Ria Novosti/Science Photo Library.

Of course things go even worse when politics begin to dominate science, as in the infamous case of Trofim Lysenko, Stalin's top biologist whose aggressive denial of the genetic theory of inheritance developed by Mendel, Morgan and many others did not only obstruct the progress of Russian biology for decades, but also possibly cost countless lives because faulty agricultural policies were based on it. In line with Marxist doctrine, for Lysenko the environment was the crucial determinant of the essence of things and he flatly rejected the idea that genes even exist — at a time when Avery, Hershey and Chase had published their main findings and Watson and Crick were well underway to unveil the structure of the hereditary material. Of course, no one now doubts the existence of genes — not even the popular press would go that far — but some of Lysenko's other tenets sound suspiciously familiar in the light of the new epigenetics hype, in particular the idea that the environment can induce heritable changes in the organism.

On the face of it, the interpretation of the new epigenetics forwarded in popular articles such as the one in *Der Spiegel*, looks just like a kind of Lysenkoism for the molecular age — with a pinch of salt of course, as it is now well known that apart from being a mischievous, power-greedy crank, Lysenko was also a fraud, while the present day research about histone modifications and methylation surely is scientifically approved. But what triggers the appeal of a quasi Lysenkoian interpretation of this research? One reason may be the sense of empowerment that speaks already from the title picture and the preposterous idea that there is a 'victory' to be had over one’s genes? Perhaps it is because this notion resonates with a public that in the eighties and nineties the same press have bullied into believing that there is ‘a gene for everything’. In that sense, the debate is remarkably similar to the one on whether we humans (or animals in general) have such a thing as a free — or conscious — will. Much like with the idea of the vulgarised genetic determinism, the scientific data that, at the very least, question the case for a clear free and conscious will are viewed as handcuffing the basic human freedom, the very essence of being human. But, while free will is being mainly defended on philosophical and psychological grounds, epigenetics seems to offer solid scientific proof — DNA modification as a kind of liberation. Structurally, then, this is the same reason why Lysenko’s ideas thrived in a Marxist system.

Apart from that, the reason for why epigenetics is so intensely and tendentiously covered in the press may simply be a journalistic one. Science journalism, where it still exists, is part of the news industry, and thus needs to be newsy; ironically, that the environment can influence the phenotype and the genes is terribly old news, no news at all, really. So, at the very least, such a story will need a human-interest factor. This is easy for fossil ancestors or cute chimpanzees, but not so easy for molecular genetics. Therefore, a larger frame has to be invoked, far-fetched as it may be. Building around the story is a legitimate literary technique to some extent, but becomes dangerous when the frame interferes with the presentation and interpretation of empirical data. In effect, it’s not far from what Lysenko did, and makes the whole purpose of science journalism questionable. It won’t cost lives as Lysenko’s mad ideas — after all, it’s only molecular biology — but the public have a right to be informed correctly. First, because they pay for the research. Second, because at the very least they need to know that science, and genetics in particular, cannot give them simple answers about who they are and how they should live, and neither can epigenetics. They’ll have to work that out for themselves and let Lysenko lie.

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Quick guide

Grasses

John Raven[1] and Howard Thomas[2]

What is a grass? A member of the Gramineae (Poaceae), the fifth largest family of flowering plants and the second largest family of monocotyledons, with over 700 genera and about 10,500 species. Lawns, cow pastures and cereal fields are, to an extent depending on the success of weed control, mainly or entirely composed of grasses. As well as these herbaceous forms, the woody bamboos are also grasses. Not every plant commonly prefixed ‘grass’ is a member of the Poaceae; grasslands are, however, dominated by true grasses. Closely related families which might be mistaken for grasses are the sedges (Cyperaceae), rushes (Juncaceae) and gondwanan Restionaceae. The Poaceae is the largest family of purely wind-pollinated seed plants.

What use are grasses? Grasses provide four of the five major crops by annual global production, and there are five grasses in the top ten. These grasses are, in decreasing order of production: sugarcane, maize, wheat, rice and barley. Grasses supply over half of the energy in human food through direct consumption and through products of grass-fed animals, as well as providing major inputs to beers and of many spirits, and, alas, gluten-related diseases. Other direct human uses of grasses include sporting and other amenity areas. Less readily quantified in monetary terms are the ecosystem services provided by the remaining semi-natural grasslands and savannas. The cultivated grasses and semi-natural grasslands together account for about 15% of global (marine and continental) primary productivity. Grasses with the C_4 photosynthetic pathway constitute about 45% of total grass species, and account for about two-thirds of grass productivity or about 10% of global primary productivity.

When did grasses evolve? Grasses originated in the Late Cretaceous about 70 million years ago: some of the last dinosaurs ate the first grasses. The earliest grasses had C_3 photosynthetic physiology; C_4 grasses evolved over 30 million years ago as atmospheric CO_2 was decreasing, although other environmental factors were also involved in the radiation of C_4 grasses in the late Paleogene and Neogene. The expansion of grasslands as a major biome began about eight million years ago, with dominance of C_4 photosynthesis in tropical to warm temperate grasslands. The semi-natural and agricultural pastures of temperate regions, based on cool-season grasses, date from establishment of human migration and trade routes over recent tens of millennia. Identifying the relative significance of the various traits that contribute to the dominance of grasslands, and of a limited number of species in grasslands, will involve further integration of phylogenetic and palaeoenvironmental studies.

How did domestication of wild grasses give rise to cereals and their weeds? Agriculture began with the domestication of wild grasses, a decisive step in the evolution of human civilization. Domestication selected variants with self-fertility, annual habit, hypertrophied grains and foliage, non-shattering seedheads, rapid establishment and growth and high harvest-index.

Wheat and barley originated in the pan-Mediterranean/Southwestern Asia region (sometimes called the Fertile Crescent). The earliest cultivated forms of wheat were einkorn (*Triticum monococcum*) and emmer (*T. dicoccum*). Modern bread wheat has a complex hexaploid genome as a result of interspecific hybridization between wild relatives. The first hybridization event combined the genomes of *T. urartu* and a probably extinct close relative of *Aegilops speltoides* into the tetraploid *T. turgidum* subsp. *dicoccoides*. Then, during the early stages of human agriculture, about 10,000 years ago, a second hybridization introduced the genome of the diploid *Aegilops tauschii*. Barley is a diploid species and there is evidence of a history of much geneflow between wild and domesticated forms. The ancestor of maize is teosinte, a group of five species of large grasses native to Central America. Teosinte was domesticated around 8,000 years ago,