The international journal of science / 21 July 2022

nature

The true legacy of Gregor Mendel: careful, rigorous and humble science

The friar's experiments laid the groundwork for genetics – and his understated approach to his work is inspirational.

Mendel studied characteristics such as flower colour in pea plants.

Genetics is fiendishly complex. We know this from decades of molecular biology, from the resulting studies on the sequencing and analysis of genomes and from our increasing knowledge of how genes interact with the environment. So how did the Augustinian friar, teacher and citizen scientist Gregor Mendel manage to describe principles of inheritance that still stand today – from work he performed alone in his monastery garden in the 1850s and 1860s?

Many of the details have been lost to history, because notes of Mendel's experiments, including his interim observations and his working methods, were burnt after his death, as Kim Nasmyth at the University of Oxford, UK, describes in a Perspective article in *Nature Reviews Genetics*[1].

But from his published works, as well as historical sources that have recently come to light, it's clear that Mendel was a careful scientist; cautious, patient and committed to data. These qualities allowed him to make discoveries that have stood the test of time. The 200th anniversary of his birth on 22 July 1822 provides an opportunity to celebrate and recognize a giant in science. "Viewed in the light of what was known of cells in the mid-nineteenth century, Mendel was decades ahead of his time," write Peter van Dijk at KeyGene in Wageningen, the Netherlands, and his colleagues in a Perspective article in *Nature Genetics*[2].

Model communication

Although Mendel had no knowledge of genes, chromosomes or genomes, he laid the foundations for genetics in a paper, 'Experiments on plant hybrids', which he presented to the Natural History Society of Brno (now in the Czech Republic) in 1865 (ref. 3). Starting with 22 plants of the garden pea, *Pisum sativum*, and using manual pollination, Mendel crossbred these specimens and their progeny multiple times, producing more than 10,000 plants over 8 years. Plants from each pollination cycle were classified according to various characteristics, such as the colour and shape of the seeds and the position of flowers. By analysing these data, Mendel discovered that certain traits – shape and colour, for example – can be passed down from one generation to the next.

> **"The 200th anniversary of Mendel's birth provides an opportunity to celebrate a giant in science."**

The paper is a model for research communication. It describes, in accessible language, how Mendel established controls and protected the integrity of his experiments (such as taking steps to reduce the risk of wind-blown or insect pollination). He is generous in crediting others' work on the subject. The final part of the manuscript includes a discussion of caveats and potential sources of error. "The validity of the set of laws suggested for Pisum requires additional confirmation and thus a repetition of at least the more important experiments would be desirable," Mendel writes in the conclusion.

Although in his paper he did coin the terms 'dominant' and 'recessive' – which remain fundamental concepts in genetics today – Mendel's caution in interpreting his results proved well-founded. Generations of geneticists and molecular and structural biologists have since demonstrated that observable characteristics do not result from genes alone. By working with model organisms and studying familial diseases and human populations, scientists have shown time and again that characteristics are influenced by an intricate interplay between a host of factors. These include RNA, epigenetics (chemical alterations to DNA bases that don't change the DNA sequence), the position of a gene within both the genome and the nucleus of a cell, and how all of the above interact with environmental factors.

And yet, as has been well documented, Mendel's name was wrongly and irresponsibly appropriated to give weight to eugenics, the scientifically inaccurate idea that humans can be improved through selective breeding. Just a few decades after his death in 1884, his work began to be discussed and cited by scientists advocating theories of racial superiority. That shadow of scientific racism – in which research and evidence are distorted to cause harm – still stalks science today.

Genetics, along with palaeontology, has gone on to provide extraordinarily precise tools for understanding human origins. Genetics has also revealed that there is

nature

more genetic variation between people in the same racial category than there is between people from different races, illustrating that there is no biological basis for what we call race. Genetics still holds many secrets, including the role of genes in human behaviour. But we now know that genes are not destiny, four words that bear repeating loudly and frequently.

In laying the foundations of genetics, Mendel set an example in his patient and comprehensive approach to collecting data. In science's current age of hyper-competitiveness, it is worth pausing for just a moment to celebrate his absolute commitment to careful observation, rigour in analysis and humility in interpreting the results.

1. Nasmyth, K. *Nature Rev. Genet.* **23**, 447–452 (2022).
2. van Dijk, P. J., Jessop, A. P. & Ellis, T. H. N. *Nature Genet.* **54**, 926–933 (2022).
3. Mendel, G. *Verh. Ver. Brünn* **4**, 3–47 (1866).

For the climate's sake, keep Arctic communication open

Pan-Arctic collaborations must continue, even if informally, between scientists inside and outside Russia.

The Arctic has long been a place where national economic interests and planetary health collide. For decades, competition for access to the region's vast oil and gas reserves has been intensifying between countries that border the Arctic. But, at the same time, those nations have been working together on a range of fronts, including research. Among their scientific collaborations are studies of the fragile Arctic environment, which is seeing ice-free days for more of the year as the globe warms.

Russia's invasion of Ukraine has drastically escalated regional tensions, and many collaborations are now in peril. Since March, the work of the Arctic Council — an intergovernmental forum comprising eight nations and six Indigenous groups — has been suspended, partly because Russia is the current holder of the body's rotating chair. Last month, the seven other nations agreed to proceed on limited work without Russia, and discussions are under way about how the role of chair might pass to Norway next year, as planned.

Scientific collaborations have been similarly affected. Much of the research and data sharing relating to the Russian Arctic is on hold, in part because of restrictions imposed by funding agencies in Europe and the United States. Moreover, a number of field experiments originally planned for the region have shifted to the North American or European Arctic. Several international efforts to study permafrost have already been disrupted as a result of economic sanctions against Russia. Although permafrost research is undoubtedly continuing in Russia, the data are no longer widely accessible — cutting off a key source of information for climate models that help researchers to predict future warming.

> **"Much of the research and data sharing relating to the Russian Arctic is on hold."**

The ebb and flow of collaboration

To some extent, such developments are not unexpected. As *Nature* reports in a Feature (see page 440), the invasion has had a negative impact on world science — and especially on collaborations between Russia, the United States and Europe. The reason, as analysts rightly point out, is that scientific collaboration often follows the ebb and flow of broader relationships between nations. When relations go cold, that inevitably affects collaborations, too. However, cutting off all research links is in no one's interests, given the severity of the global problems humanity faces.

The Arctic is warming at least three times as fast as the global average; the Norwegian archipelago of Svalbard has just reported its warmest June on record. Melting sea ice is wreaking havoc with hunters' livelihoods; thawing permafrost is causing serious subsidence that can destroy buildings and roads; and wildfires are sending thick palls of smoke into northern cities.

In the face of the war in Ukraine, it might seem tempting to set aside science and climate cooperation for the time being. But that would be short-sighted. Russia makes up about half of the circumpolar Arctic, and plays a crucial part in monitoring environmental change across the region. The necessity of tackling climate change means it is crucial that Arctic nations' researchers, funders and research policymakers find creative ways to keep lines of communication open.

Some projects are nearing completion. Ways can surely be found to progress these and see them through to completion. For example, a draft assessment of natural and anthropogenic radioactivity across the Arctic is almost complete and needs to be published when ready. It falls under the Arctic Monitoring and Assessment Programme and incorporates previous input from Russian scientists.

Like people around the world, Arctic residents are increasingly worried about food and energy security. The war in Ukraine has sent fuel prices skyrocketing, adding cost and complexity to the often resource-strained effort of living in the far north. This must not be forgotten as public attention focuses on concerns elsewhere.

At the same time, all efforts to maintain research collaboration (where safe and where possible) need to be sustained. It is unwise — indeed, counterproductive — when regional and bilateral tensions end all science links. This didn't happen during the cold war. It hasn't happened during some of the twentieth and twenty-first centuries' other conflicts. It must not happen now.