Review Paper

Genes and Genius: The Inheritance of Gregor Mendel

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Gregor Mendel. Does the name stir anything now, after 140 years? Perhaps we acknowledge a remote debt. “The Father of Genetics.” Honorable, but also rather automatic, taken for granted. A pioneer, a founder—but, as such, a character from a mythic realm. We probably recall something about what he did. Crossbred peas. Recorded variations. Identified dominant and recessive traits. But can such a distant figure still have a meaningful connection to us?

The new exhibit Gregor Mendel: Planting the Seeds of Genetics, at Chicago’s Field Museum through April 1, 2007, goes beyond the textbook accounts to explore the driven, very human scientist that started it all. Mendel has been labeled “the first geneticist,” because he discerned “laws” of heredity that were later named after him. He is sometimes referred to as “a botanist” because he experimented on pea plants. Those of us with good memories may recall his story in more detail: through 8 years of meticulous experimentation crossbreeding different varieties of Pisum sativum, the garden pea, Gregor Mendel was able to discern the fundamental laws of heredity by analyzing the mathematical ratios he found in the hybrid offspring of his plants. We may even recall that he was a monk.

That’s the essence of the story, but it’s in the details of his life and his contributions that the power of Gregor Mendel’s accomplishment—his genius—emerges. It’s there that we discover not an inspired amateur, or a determined little gardener (images of Mendel that still circulate), but a dedicated, driven, brilliant scientist. He was more mathematician than gardener, as much a physicist as a botanist. It’s true that peas held the key to his discovery, but Mendel also experimented on dozens of plant species, including ornamental flowers and beans. We were taught that he was a monk, but he was, in fact, a friar. It’s a crucial distinction—in fact, it’s one of the telling details in Mendel’s story, a fundamental factor in his scientific achievement.

A monk could not have done what Mendel did. Monks are cloistered, tied to their monastery, while a friar is required to go out into the world. From its founding in 1256, the Augustinian order, to which Mendel belonged, focused on education and scientific study as well as missionary work. In addition, the abbey (not monastery) that Mendel belonged to in Brunn, Moravia (now Brno, Czech Republic) was peculiarly engaged in the larger world of culture and science. Its head, Abbot Cyril Napp, was a scientist himself, and held progressive views; in addition, the friars of St. Thomas were required by the Austrian government of the time to teach in the public schools. The fact that Mendel was a friar at this precise place and time was one of the keys to his discovery.

It was probably a long-standing scientific inclination that led Mendel to the Augustinians. Johann Mendel (as he was christened) was a farm boy, and learned about agriculture and fruit growing from his father. His local school was advanced for its time, offering natural science as part of its curriculum. He was a bright student, and pursued an academic track that few boys of his means could. But life was difficult—he struggled, and half-starved supporting himself through secondary school. And then what? His prospects for becoming a teacher were dim. Back to the farm? The Abbey of St. Thomas offered another alternative: a scholarly community (and a well-laden refectory table). As he put it in an autobiographical sketch (quaintly, in the third person), “his circumstances determined his vocational choice.” He joined the order in 1843, at age 21; the decision marks the beginning of his transformation into a scientist.

Mendel’s fellow friars included botanists, philosophers, a mathematician, and a composer; most taught in secondary schools or universities. Mendel himself was sent to teach in local schools after proving to be unsuited to parish work (visiting the sick and dying drove him to illness). He was put in charge of the Abbey’s natural history collections, and soon became a member of the local agricultural society (and a few years later led a breakaway group to form the Brunn Natural Science Society). But the Abbey offered more than a rich intellectual environment: it provided Mendel an entry into more advanced scientific training. After Mendel failed a teaching qualification exam in 1851, his abbot sent him to study at the University of...
Vienna. This foundation would prove to be crucial in the formation of Mendel as a scientist. Mendel studied with eminent physicists like Christian Doppler, a promoter of probability theory, and Andreas Baumgartner, who emphasized mathematical approaches to the study of nature. He also took courses with Franz Unger, a prominent botanist and an early proponent of cell biology—and an advocate of statistical analysis of natural phenomena—as well as mathematician Andreas von Ettingshausen, a major figure in the development of combinatorial mathematics. Here again, the intellectual context shaped the future findings; had Mendel shone as a parish priest—or passed his teaching exam—the basic laws of heredity might today be named after someone else.

Back from the university in 1854, Mendel settled in as a teacher—and began planning his pea experiments. The influence of his years in Vienna are clear in his study. In short, he used statistical analysis and probability theory to infer the mechanics that must be going on at the cell level. But it was not only his academic foundation that determined his groundbreaking methods. If it were just exposure to statistics and probability theory that turned the key, surely it would not have taken others another 30-plus years to unlock the secrets Mendel did.

No, the crucial factor was the unique insight Mendel brought to the plant hybridization experiments that had long interested him. He had been crossbreeding ornamental plants (and possibly white × gray mice) well before Vienna. Through his systematic experiments on some 12,000 or more pea plants between 1856 and 1863, he posited the existence of hereditary “elements” or “factors” in the reproductive cells of the plants, more than 10 years before cell biologists could see chromosomes through their microscopes, and more than 3 decades before scientists made the connection between chromosomes and heredity.

It’s safe to say that no major scientific discovery ever had such a delayed impact. Mendel published his findings in the journal of his local natural science society in 1866. Although the paper was cited in a handful of botanical studies, its significance was overlooked until 1900. Mendel corresponded with an eminent botanist, Carl von Nägeli, the contemporary perhaps best equipped to grasp the significance of the pea paper (he was interested in plant breeding and cell theory)—but Nägeli didn’t get it. It may be that Mendel’s mathematical approach was simply too far above the heads of the people who would have been most interested in his results. Where his pre-

The friars of St. Thomas circa 1862. Gregor Mendel is standing, second from right, holding a *Fuschia*, his favorite flower. Photo courtesy of the Mendel Museum, Brno, Czech Republic.
deceivers and contemporaries (include Darwin here) provided general description of traits, Mendel laid out pages and pages of symbols, equations, and ratios.

It sounds clichéd to say that Mendel was ahead of his time, but he was. It was not until the turn of the century that scientists started doing work in the same vein. When his work was "rediscovered," the study of heredity was dubbed "Mendelism," and the tag remained until Mendel’s most dogged promoter, British zoologist William Bateson, came up with “genetics” in 1906. So, for a time Mendel had a science named after him. Yet somehow his star has faded. His pea study is considered one of the three most important publications in the history of biology (along with Darwin’s Origin and Watson and Crick’s account of the structure of DNA), yet as a scientist he is far overshadowed by them. While Darwin and Einstein have become cultural icons, Mendel is a dimly remembered name from biology class. Half of the visitors in a 2004 Field Museum survey could not place him.

Still, the other half could. Some, perhaps predictably, remembered him as a geneticist or a botanist. They weren’t wrong, although not precisely correct either. Mendel wasn’t really a geneticist (genes had not even been conceived of, let alone named), although he was certainly theorizing about the mechanics of what we now call genes. Nor was he a botanist, although plant breeding was one of his central interests (but he also crossbred different species of bees). In fact, the closest thing to a scientific profession he had was meteorologist—he was an official weather recorder for Moravia, and published more on meteorology than plant breeding (another connection to the peas: observing variations and tabulating data). As a teacher, his specialties were physics and mathematics. So . . . a botanically inclined mathematician? A mathematical crossbreeder? An experimental botanist? More than likely have Mendel would have simply called himself a “naturalist.”

Today, we have specialties. Evolutionary biologist. Population geneticist. Systematist. Molecular ecologist. Conservation geneticist. Mendel was perhaps fortunate in not achieving such a professional academic status. He was free to pursue his work driven only by a passion for understanding the workings of the natural world. For those of us who pursue questions of natural history at the molecular level, our debt to Mendel is strong, but it’s a debt that is, admittedly, easy to overlook. Prior to working on this exhibition we knew the name “Mendel,” but we did not know the man. Having worked on this exhibit over the last 2 years, the connection has become much deeper. We came to know not the mythic Mendel, but the human one: his struggles, his determination, his passion—the same characteristics that define his modern scientific heirs.

One goal of the exhibition, for us, was to underscore that
scientists are human beings. Mendel was a real person—like us. He was hard working, fun loving, fallible, obsessed with his work. He flunked his teaching exams, giving ridiculous answers to some questions—a fact that struck a chord with those of us who, perhaps ironically, struggled with biology in younger days. He taught physics and mathematics by day and pursued his research in his off time. He all but ruined his eyes examining minute plant parts and peering through microscopes in poor light. The bittersweet story of Mendel’s obscurity and rediscovery is a very human one, but perhaps particularly poignant for scientists. Surely he felt some disappointment when his work went unrecognized. When we send our research out into the world to face judgment by our peers, we are sending part of ourselves. We submit, and wait. We hope for praise and lively discussion, but rejection, criticism, and silence are equally possible. Hard to say which is worse—being read and misunderstood/dismissed, or being completely ignored. Like Mendel, we develop thick skin, and carry on because we believe in the significance of what we do.

That’s the human connection. Is there a special resonance for geneticists? There should be. It’s difficult to conceive of any aspect of modern biological study that does not trace back to Mendel in some way. The continuities are many. Mendel was working in a place and time of intensive concern for agricultural improvement, one more practitioner in a long tradition of crossbreeding—his modern counterparts have added recombinant DNA technology to the arsenal of methods. No doubt Mendel would be dumfounded by headline-grabbing genetic applications like human cloning, designer babies, gene therapies, genetically modified crops, immune therapies for disease treatment, and the like—yet, all the paths eventually lead back to him, whether via the notion of the gene itself, or through such scientific “descendants” as William Bateson, T.H. Morgan, Nettie Stevens, E.B. Wilson, Barbara McClintock, Oswald Avery, or Watson and Crick.

It would be impossible to even scratch the surface of all the research that would constitute part of Mendel’s legacy. The Field Museum exhibit introduces visitors to several “Modern Mendels,” scientists working on the natural history of organisms using genetic techniques. At the Field’s Pritzker Laboratory for Molecular Systematics and Evolution there are more than 40 research projects underway, focusing on a multitude of taxa from all continents, and employing a wide variety of scientific approaches. The projects have one element in common: tracing the genealogy of organisms using DNA. The amazing thing about all life is that it is tied together by four nucleotides: Guanine, Adenine, Thymine, and Cytosine. Thus, once we extract DNA from our organism of choice, the methods we use are remarkably similar. Scientists in the Pritzker Lab are using DNA to examine a range of relationships, from individual family members to relationships between phyla: DNA sequence data are being used to examine major lineages of birds, the phyleogeography of bipolar lichens, the diversity of Peruvian mammals, and geographic variation of southeast Asian frogs, to name just a few examples; other projects are developing microsatellite markers to examine the mating systems in peregrine falcons, lemon sharks, African trees, kelp, water snakes, and cowbirds; and a recently initiated project uses T-RFLP data to identify species of fungi. The spirit of Mendel hovers over these projects too—he was not simply interested in the variations in the pea and flower hybrids that emerged from his experiments, but what those studies revealed about larger patterns in nature, and the hidden cellular processes behind it all.

As molecular biologists we trace genealogies using DNA-based methods with the far-reaching goal of understanding where all organisms fit on the tree of life. There are, however, many ways of tracing roots. In this exhibition, we are given the rare opportunity to trace the intellectual roots of our science. There is no question that Mendel is still relevant to the field. His work is still discussed in genetics and botany journals, still cited in research articles. But he also speaks to us by his example. In his classic pea paper Mendel wrote that although his approach—detailed experiments and the application of statistical analysis—was daunting, “it seems to be the one correct way of finally solving a question whose significance for the evolutionary history of organic forms must not be underestimated.” We remember Mendel most of all for that unflagging curiosity and almost obsessive determination—much the same forces that drive us, his scientific heirs, to address the myriad mysteries of heredity that remain to be solved.

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