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## Beyond the Monastery Walls: The 160-Year Journey to Mendel's Seven Genes

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In 1866, Gregor Mendel established the foundations of genetics by analysing seven contrasting traits in 28,000 pea plants (*Pisum sativum*). While his laws of inheritance—Segregation and Independent Assortment—transformed biology into a predictive science, the physical nature of his "factors" remained a mystery for over a century. This article explores Mendel's rigorous experimental journey and highlights the recent breakthrough in plant genomics: the successful cloning and functional characterisation of all seven Mendelian genes. By bridging 19th-century observation with 21st-century sequencing, we finally reveal the molecular engines—from growth hormones to transcription factors—that drive the classical traits of the world's most famous garden

### Introduction

#### *The Architect of Heredity*

**Gregor Mendel** (born July 20, 1822, Heinzendorf, Silesia, Austrian Empire [now Hynčice, Czech Republic]—died January 6, 1884, Brünn, Austria-Hungary [now Brno, Czech Republic]) was a botanist, teacher, and Augustinian prelate. He was the first person to lay the mathematical foundation of the science of genetics, in what came to be called **Mendelism**. Born into a German-speaking family of limited means, Mendel's journey was defined by a relentless curiosity. While his early life was rooted in the rural soil of his family's farm, his mind was shaped by the rigorous logic of physics and mathematics at the University of Olmütz and the University of Vienna. It was here, under the tutelage of greats like Christian Doppler (discoverer of the Doppler effect), that Mendel learned to see the natural world through the lens of discrete units much like the atoms and molecules of physical science.



**The Father of Genetics, Johann Gregor Mendel.**

#### *Mendel's Work: A Unified Quest: From Honeybees to Hawkweed*

While Mendel's work is famously synonymous with the garden pea, his curiosity about the laws of nature drove him to experiment with a diverse array of life far beyond the walls of his monastery garden. To test the universality of his findings, he expanded his research to include other crops like maize and common beans, where he first glimpsed the complexities of traits like flower colour that didn't always fit his simple ratios. He famously spent seven years struggling with the elusive hawkweed, a plant that nearly derailed his theories because its unusual reproductive methods were unknown to science at the time. His reach even extended into the animal kingdom; as a master beekeeper, he attempted to cross-breed different races of honeybees to see if inheritance followed the same mathematical patterns in insects as it did in plants. He even began early studies on the coat colours of mice in his own quarters, a project that was reportedly halted by his bishop, who found a monk's focus on animal mating

to be inappropriate. These wide-ranging efforts demonstrate that Mendel was not just a pea breeder but a pioneer searching for a unified theory of biology.

**Experimental Rigour:** *The Mathematical Secret: 28,000 Plants*

Mendel's path to discovery began with a remarkably disciplined two-year search for the perfect biological subjects. Rather than rushing into crosses, he spent those first years meticulously testing at least 34 pea varieties, ruthlessly discarding any that showed inconsistent or "medium-sized" traits. He eventually kept only 22 purebred varieties with a clear, "either-or" genetic background to ensure his data remained mathematically precise. Over the next eight years, Mendel performed thousands of painstaking cross-pollinations, raising approximately 28,000 plants. This massive sample size was his "secret weapon"; it allowed him to see mathematical ratios that others had missed, transforming the simple act of gardening into a rigorous statistical map of life.

**Laws & Publication:** *A Message in a Bottle: The 1866 Blueprint*

The culmination of this work was presented in 1865 at two meetings of the Natural History Society of Brno. A year later, in 1866, he published his findings in the society's journal under the title *Versuche über Pflanzen-Hybriden* (Experiments on Plant Hybridisation). From this mountain of data, Mendel distilled two fundamental pillars of genetics: the Principle of Segregation, which explains how individual "factors" for a trait separate and recombine in offspring, and the **Law of Independent Assortment**, which observes that different traits are inherited independently of one another—like separate hands in a card game. While his paper remained largely ignored for over three decades, its "rediscovery" in 1900 by three independent botanists finally proved that inheritance wasn't a messy mixing of fluids, but a precise shuffle of physical units of information.

**Molecular Reveal:** *The Seven Wonders: Mapping the Genetic Engine*

**Table 1 Name:** *The Molecular Identity of Mendel's Seven Functional Traits.*

SL.No	Character	Contrasting Phenotypes	Allele Notation	Chromosome Number	Molecular Characterisation
1.	Seed Shape	Round / Wrinkled	R / r	3	PsSBE1: Starch branching enzyme with a 1,021-bp Ips-r element insertion.
2.	Cotyledon Color	Yellow / Green	I/i	1	PsSGR (Stay-green): Mg-dechelataase; mutants have a retrotransposon insertion or promoter deletion.
3.	Flower Color	Purple / White	A / a	6	PsbHLH: A basic helix-loop-helix transcription factor regulating anthocyanin.
4.	Stem Length	Tall / Dwarf	Le / le	5	PsGA3ox1: Gibberellin 3-oxidase (growth hormone); dwarfism is a single G>A substitution.
5.	Pod Color	Green / Yellow	Gp / gp	3	PsChlG: Chlorophyll synthase; yellow pods result from a 100-kb genomic deletion.
6	Pod Shape	Inflated / Constricted	P, V / p, v	2 (P) & 4 (V)	PsCLE41 (P) & PsMYB26 (V): Disrupt secondary cell wall thickening/lignification.
7.	Flower Position	Axial / Terminal	Fa/fa	4	PsCIK2/3: A CIK-like co-receptor kinase; terminal positioning involves a 5-bp exonic deletion.

**Rediscovery: *The Outsider's Triumph: From 'Empirical' to 'Essential'***

Despite the transformative potential of his 1866 publication, Mendel's work remained a "message in a bottle" for thirty-four years. The silence was finally broken in 1900 when Hugo de Vries, Carl Correns, and Erich von Tschermak independently reported similar hybridisation results. While de Vries and Correns had read Mendel's work earlier and "forgotten" it, rereading his paper allowed them to organise their own diverse data into a rational system. Tschermak, who initially interpreted his 3:1 ratio as "unequal valency," only later incorporated Mendelian theory into his texts.

In Great Britain, William Bateson became the leading proponent of "Mendelism," though he faced fierce opposition from Darwinians who considered the work irrelevant to evolution. It took decades to bridge this gap, with Wilhelm Johannsen finally naming the determinants "genes" in 1909 and Thomas Hunt Morgan locating them on chromosomes by 1913. Historians suggest Mendel's initial failure in the scientific world was due to his status as an "outsider"; his "farmer-like" empirical thinking was distrusted by elite scientists like Carl von Nägeli, who dismissed Mendel's experimentally proven laws as "rationally unproven." Whether Mendel was a visionary geneticist or a botanist focused on hybridisation, his rediscovery ultimately proved his own prophetic words: "*My time will yet come.*"

**Conclusion: Closing the 160-Year Circle**

The transition from Mendel's paper ledgers to modern DNA sequencing marks a profound evolution in biological thought. The recent identification of the final elusive genes governing pod architecture and flower position has finally transformed Mendel's abstract mathematical principles into concrete biochemical realities. This milestone does more than satisfy historical curiosity; it provides a functional map for the future of agriculture. By understanding the precise alleles underlying these foundational traits, scientists can now use genome-editing tools such as CRISPR to enhance crop resilience and food security. One hundred and sixty years later, the "factors" Mendel meticulously counted have become the very code we use to engineer a sustainable future, proving that his time has truly come.

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