

19th-Century Algebra

Since early Mesopotamian times people have solved quadratic equations using only arithmetic operations and the taking of roots, and in the 16th century Italian mathematicians developed similar methods for solving polynomial equations of degrees 3 and 4. But little progress was made in finding general solutions for equations of degree 5 or more.

In 1826, during his travels in France and Germany, the Norwegian mathematician **Niels Henrik Abel** (1802–1829) proved that no such general solution can exist. He also obtained fundamental results on elliptic functions and the convergence of series, and several mathematical concepts are named after him. A monument to Abel by Gustav Vigeland was erected in Oslo in 1908.

Abel's work was extended by the brilliant young French mathematician **Évariste Galois** (1811–1832), who investi-

gated which equations *can* be solved by radicals. Galois had a short and turbulent life. He was sent to jail for political activism, and he died tragically in a duel at the age of 20, having sat up the previous night summarising his mathematical achievements for posterity.

William Rowan Hamilton (1805–1865) was a child prodigy, discovered an error in Laplace's celestial mechanics while a teenager, and became Astronomer Royal of Ireland while still an undergraduate. While attempting to generalize the complex numbers to three dimensions, he discovered a "noncommutative system," his *quaternion* expressions of the form $a + bi + cj + dk$, where

$$i^2 = j^2 = k^2 = -1 \text{ and } ij = -ji, jk = -kj, ik = -ki$$

Charles Lutwidge Dodgson (1830–1898) is better known as Lewis Carroll, author of *Alice's Adventures in Wonderland*. A mathematics lecturer at Oxford University who wrote on geometry, algebra, and logic, his 1867 treatise on determinants contained the first printed appearance of the Kronecker-Capelli theorem, and it included his "condensation method" for reducing the calculation of large determinants to those of order 2.



Abel



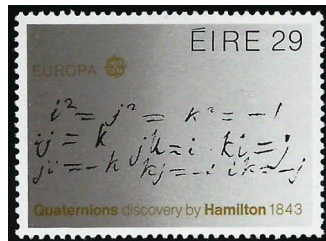
Abel memorial



Galois



Hamilton



Hamilton's quaternions



Dodgson

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