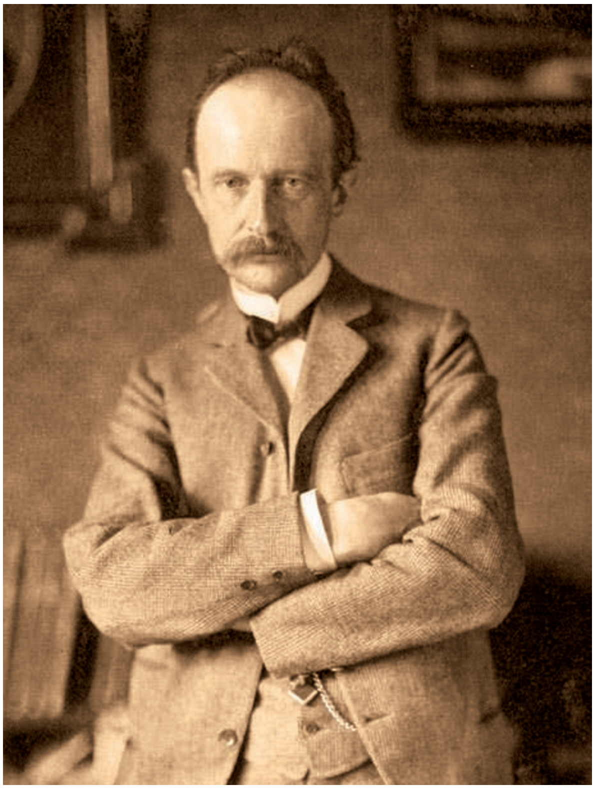
MILESTONE 3

# The quantum leap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"With the discovery of the principle of energy conservation, the edifice of theoretical physics is fairly complete. There will be a mote to wipe out in a corner here or there, but something fundamentally new you won't find." So spoke Philipp von Jolly when, in 1877, his student Max Planck left Munich for Berlin, to spend his last year of studies there.

Planck, undeterred, went into theoretical physics — not hoping to make new discoveries, but driven by his admiration of its elegance. His main interest was thermodynamics, but works by Otto Lummer and Ernst Pringsheim, and by Heinrich Rubens and Friedrich Kurlbaum, which aimed at constructing a standard for the measurement of illumination intensities, directed him towards heat radiation. He revisited Gustav Kirchhoff's theoretical studies of black-body radiation, which implied that when a substance capable of absorbing and emitting radiation is enclosed in a cavity with perfectly reflecting walls, the spectral distribution of the observed radiation at equilibrium is a function only of temperature and is independent of the substance involved. Intrigued by such an 'absolute' law, Plank devoted himself, from 1896, to finding an explanation for it.

Parallel works on black-body radiation produced confusing results. Lord Rayleigh had found a law (which, with James Jeans, he later refined) that well described the emission spectrum at long wavelengths, but failed at short ones. By contrast, an earlier law by Wilhelm Wien describing the frequency position of the radiation maximum — which had been observed experimentally, but was not reproduced by the Rayleigh–Jeans theory — held for short, but not for long, wavelengths. By October 1900, Planck had found a formula that interpolated between the curve of Rayleigh and Jeans and that of Wien. He sent his result, by postcard, to Heinrich Rubens, who immediately compared it to experimental data. It fitted all observations perfectly. Spurred by the agreement, Planck set about finding the physical character of his empirical formula.

On 14 December 1900, he presented the outcome in a lecture given to the German Physical Society. Planck had indeed found a sound derivation to explain the behaviours described by his formula, partially guided by the work of Ludwig Boltzmann on entropy. However, there was one revolutionary assumption that he had to make: that light was emitted and absorbed in discrete packets of energy — quanta. These were not a feature of heat radiation alone, but, as Albert Einstein showed in 1905, also of light. Einstein used the term *Lichtquant*, or quantum of light. Only in 1926 was the word 'photon' introduced, by the chemist Gilbert Lewis. His theory of a "hypothetical new atom that is not light but plays an essential part in every process of radiation" did not hold up, but the name 'photon' stuck.

Without setting out to do so, Planck had rocked the edifice of physics to its very foundations. "His was, by nature, a conservative mind," wrote Max Born in an obituary of Planck, "he had nothing of the revolutionary and was thoroughly sceptical about speculations. Yet his belief in the compelling force of logical reasoning from facts was so strong that he did not flinch from announcing the most revolutionary idea which ever has shaken physics."

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