Development

(1900) Max Planck's quantum hypothesis

$$E = h\nu \tag{1}$$

for the emission of EM radiation, where ν is the frequency of a wave and $h = 6.626 \times 10^{-34}$ J·s.

(1905) Albert Einstein explains the photoelectric effect using this quantum hypothesis. Photons have momenta given by

$$p = h/\lambda \tag{2}$$

where λ is the wavelength.

(1913) Neils Bohr proposes that electrons in atoms have wavelike properties and could exist in atoms only at precise energy levels. Transitions between energy levels explained spectral lines.

(1924) Louis De Broglie proposes that all particles have a wave-like nature with wavelength given by

$$\lambda = h/p \tag{3}$$

where p is the momentum. This is the same as eqn. (2). This is called "wave-particle duality." In some contexts things behave like waves, in others like particles.

[1] What is the de Broglie wavelength of an electron ($m = 9 \times 10^{-31}$kg) moving at (a) 1 m/s, and (b) 1.5×10^8m/s?

(a) $\lambda = 6.626 \times 10^{-34}/(9 \times 10^{-31} \cdot 1) = 7.3 \times 10^{-4}$m

(b) $\lambda = 6.626 \times 10^{-34}/((9 \times 10^{-31}) \cdot (1.5 \times 10^8)) = 4.9 \times 10^{-12}$m

[2] For electrons moving sufficiently fast, are their wavelengths longer or shorter than visible light? Shorter.

[3] Would you get better resolution from fast electrons or from visible light for devices such as microscopes? Fast electrons.

(1924) Satyendra Nath Bose introduces a statistical theory explaining Planck's theory of radiation. He sends his work to Einstein who has it published and adds an extension of his own. The particles to which these Bose-Einstein statistics apply are now bosons. They are the quanta of interactions (photons, gluons, etc.).

(1925) Werner Heisenberg introduces the first full quantum theory, putting together previous pieces of work, using the mathematics of matrices: matrix mechanics.

(1926) Erwin Schrödinger introduces a different formulation of quantum mechanics using the mathematics of wave motion: wave mechanics. Schrödinger's wave mechanics is the most commonly used version of quantum mechanics today. Every system is describe by a function of space and time, $\psi(x,t)$, called its wave function. The wave function obeys an equation called Schrödinger's equation. In one space dimension it is

$$i\hbar \frac{\partial \psi(x,t)}{\partial t} = \frac{-\hbar^2}{2m} \cdot \frac{\partial^2 \psi(x,t)}{\partial x^2} + V(x)\psi(x,t)$$

where $\hbar = h/2\pi$, m is the mass, and $V(x)$ the potential energy.

Schrödinger did not correctly interpret his own wave function.

(1926) Max Born provides the correct interpretation of $\psi(x,t)$: $|\psi(x,t)|^2$ is the probability of finding a particle at a point x at time t.

(1926) Enrico Fermi discovers the relationship between the spin of particles and the statistical laws they follow: fermions have half-integer spin (related to angular momentum in units involving $\hbar$) and bosons have integer spin.

(1926) Paul Dirac shows that wave mechanics was mathematically equivalent to matrix mechanics. He also introduced the statistical laws that apply to particles such as electrons. The class of particles to which Fermi-Dirac statistics apply are called fermions. They are the quanta of matter (electrons, quarks, neutrinos, etc.).

(1927) Heisenberg introduces the uncertainty principle:

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

where Δx and Δp are the "uncertainties" (related to standard deviations) in position and momentum, respectively. If you try to measure one variable, say x, to a high degree of accuracy, the value of the other variable, p, automatically becomes highly uncertain.

(1927) Dirac introduces relativistic quantum mechanics and applies it to the electron. This theory makes quantum mechanics consistent with special relativity. A version that is consistent with general relativity has proved elusive to this day (April 21, 2016).

(1930) Dirac predicts, based on his theory of the electron, that the mathematics dictates the existence of an electron antiparticle – the positron (opposite charge, but otherwise identical). We now believe every fundamental particle has an antiparticle. Matter-antimatter asymmetry is a puzzle.

(1930s and 1940s) Lots of developments using QM to explain chemistry, the structure of the nucleus, the structure of stars, etc.

(1948) Sin-Tiro Tomonaga, Julian Schwinger, and Richard Feynman independently show how the infinities that arise when you applied relativistic quantum mechanics to the electromagnetic field could be handled. Feynman's approach uses "path integrals" – where system choose the path they take by sniffing through all possible ones.

(1960s) Schwinger and Sheldon Glashow produce a unifies quantum field theory that unifies the weak nuclear force and electromagnetism.

(1960s and 1970s) Quarks are introduced and the Higgs boson. The work of many people leads to Grand Unified Theories that provide a quantum field theoretical unification of the strong and weak nuclear forces and electromagnetism. Gravitation remains the odd "force" out. If it is "quantized" then its particle, the graviton, must have spin 2. Supersymmetry is introduced, providing a possible link between fermions and bosons.

(1974) Stephen Hawking does one of the first successful calculations of quantum field theory in a curved spacetime, and arrives at the result that blacks holes can radiate.

(1982) Alan Guth, studying grand unified theories in the early universe to explain the suppression of magnetic monopoles, proposes an extension of the big bang theory called inflationary cosmology.