logically consistent mathematical formulation, but they did not always know how to use it to describe a given experimental situation. Heisenberg recognised that the root of these difficulties was the lack of a definite interpretation of the formulations, and he spent the following months in intensive, exhausting and often highly emotional discussions with Bohr, Schrödinger and others, until the situation was finally clarified.

Heisenberg recognised that the formulation of quantum theory cannot be interpreted in terms of our intuitive notions of space and time, or of cause and effect; but at the same time he realised that all our concepts are connected with these intuitive notions of space and time. He concluded that there was no way out other than to retain the classical intuitive notions but restrict their applicability.

Heisenberg's great achievement was to express these limitations of classical concepts in a precise mathematical form, which now bears his name and is known as the Heisenberg uncertainty principle. It consists of a set of mathematical relations that determine the extent to which classical concepts can be applied to atomic phenomena and thus stake out the limits of human imagination in the subatomic world.

At the most fundamental level, Heisenberg's uncertainty principle is a measure of the unity and interrelatedness of matter. We have come to realise in modern physics that the material world is not a collection of separate objects, but rather appears as a network of relations between the various parts of a unified whole. This shift from objects to relationships has far-reaching implications for science as a whole. It is most apparent in ecology, a science that was emerging around the time Heisenberg formulated his uncertainty principle. Like subatomic particles, the phenomena we observe in ecosystems do not have intrinsic properties, but can only be understood in terms of their mutual relationships.

In quantum physics, our classical notions, derived from our ordinary experience, are not fully adequate to describe the atomic and subatomic world. The concept of a distinct particle, for example, is an idealisation that has no fundamental significance. When we describe the properties of such an entity in terms of classical concepts such as position, energy or velocity, we always find pairs of concepts that are interrelated and cannot be defined simultaneously in a precise way. The more we impose the one concept of the physical object, the more the other concept becomes uncertain, and the precise relation between the two is given by the uncertainty principle.

Like no one else, Werner Heisenberg explored the limits of human imagination, the limits to which our conventional concepts can be stretched. His greatness was that he not only recognised these limitations and their profound philosophical implications, but also was able to stake them out with mathematical clarity and precision. R

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"Happy 50th anniversary, *Resurgence*! My family and I have been involved in animal welfare and vegetarianism for many years now and would like to congratulate you for the good work you do for the planet and creatures who live on it. Best wishes for the future."

– Sir Paul McCartney