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Research Highlights

Nobel Prize 2008: Nambu, Kobayashi & Maskawa

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The 2008 Nobel Prize for physics has been awarded to Yoichiro Nambu "for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics", and to Makoto Kobayashi and Toshihide Maskawa "for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature".

This year, fundamental physics is once again the focus of the Nobel committee, with the award of the prize for theoretical work that underpins the standard model of particle physics.

Yoichiro Nambu is acknowledged for his work in the 1960s on spontaneous symmetry breaking in quantum field theory. The concept of spontaneous symmetry breaking already had currency in condensed-matter physics — from Heisenberg's 1928 theory for magnetism to the BCS theory of 1957. Nambu[1,2] developed the idea in the field-theoretic context for elementary particles, laying a cornerstone of what would later become the standard model.

A crucial step in his theory was the introduction of vacuum expectation values for certain fields. Subsequent development of Nambu's ideas, particularly by Jeffrey Goldstone, Robert Brout, Francois Englert and Peter Higgs, culminated in the 'Higgs mechanism' — the spontaneous breaking of a gauge symmetry that is favoured as an explanation of particle masses and suggests the existence of the Higgs boson (the particle eagerly sought at Fermilab's Tevatron and CERN's Large Hadron Collider).

The prize-winning work of Makoto Kobayashi and Toshihide Maskawa is also linked to symmetry — specifically, why there isn't perfect symmetry between matter and antimatter.

Following work by Nicola Cabibbo, who had found a universal parameter (the 'Cabibbo angle') in the interactions of two 'generations', or families, of quarks, in the early 1970s Kobayashi and Maskawa[3] extended the formalism to three generations, involving a population of six quarks. Only three quarks were then known to exist — the up and down quarks, and the heavier strange quark. But subsequent discoveries — of the charm quark in 1974, the bottom quark in 1977 and the top quark in 1995 — confirmed Kobayashi and Maskawa's picture of six quarks paired into three generations according to their masses.

Moreover, the Cabibbo–Kobayashi–Maskawa, or CKM, matrix — a 3×3 matrix whose elements describe the 'mixing' (or interaction) between the six quarks — also includes a phase angle. That's significant, as it allows for the phenomenon of

charge–parity violation (discovered in 1964 by James Cronin and Val Fitch) and a subtle difference between matter and antimatter. This violation could be part of the explanation for why the Universe is made of matter and not antimatter.

REFERENCES

1. Nambu, Y. Quasi-particles and gauge invariance in the theory of superconductivity. *Phys. Rev.* **117,** 648–663 (1960).

2. Nambu, Y. in *Broken Symmetry: Selected papers by Y. Nambu* (eds Eguchi, T. & Nishijima, K.) 110–126 (World Scientific, 1995).

3. Kobayashi, M. & Maskawa, K. CP violation in the renormalizable theory of weak interactions. *Prog. Theoret. Phys.* **49,** 652 (1973).