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Nambu, A Foreteller of Modern Physics II

Nambu, at the beginning

The late 1950s and early 1960s were a time of despair for physicists trying to understand the strong interactions. One approach that seemed to offer some hope was the study of the currents that define the weak and electromagnetic interactions of hadrons with leptons. In particular, Feynman and Gell-Mann had given evidence that the vector current of beta decay is conserved, like the electromagnetic current, but it seemed impossible to extend this to the axial current of beta decay. Nambu's historic breakthrough was to propose that we should think of the axial vector current as conserved in a peculiar approximation, in which the pion mass vanishes. Nambu showed that this conservation law led to a relation between the pion nucleon coupling, the axial vector beta decay coupling constant, and the amplitude for charged pion decay, which had previously been obtained by Goldberger and Treiman on the basis of implausible approximations, but was known to work pretty well experimentally. But now Nambu had shown that the Goldberger–Treiman relation is exactly valid in the limit of vanishing pion mass. Nambu and his colleagues later went on to derive other results for the emission of single soft pions in hadronic reactions.

Nambu also tackled the problem of understanding the sort of dynamical theory in which the axial current would be conserved and the pion massless. With Jona-Lasinio he constructed such a model, with the pion appearing as a nucleon–antinucleon bound state. The model was based in part on an analogy with the BCS theory of superconductivity.

With the benefit of hindsight, we can say that the predictions of both the BCS theory and the Nambu–Jona-Lasinio model were consequences of symmetries of these theories that were spontaneously broken. A symmetry like that of the Nambu–Jona-Lasinio model arises in quantum chromodynamics because two quark types are relatively light. What made this symmetry far from obvious is that it is not only spontaneously broken, it is not even exact to begin with, because these quark masses are only small, not zero. Spontaneously broken symmetries were to play an increasingly important role in the future, both in the theory of soft pions and in the development of the Standard Model, but their first appearance in particle physics was in the work of Nambu.

I regret that I never had the opportunity to work with Yoichiro, but, like many theoretical physicists of my generation, I am deeply grateful to him for the insights provided by his work.

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