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# This Week's Citation Classic

**Ne'eman Y.** Derivation of strong interactions from a gauge invanance. *Nuclear Phys.* 26:222-9, 1961. [Department of Physics, Imperial College, London, England]

The known hadrons are classified as octets of SU(3). Strong interactions should be approximately invariant under this symmetry. A spinless meson and an octet of spin-one mesons are predicted. This paper introduced SU(3) with correct particle assignments. It led to quarks, current algebra, SU(6), charm, color, etc. [The ***SCI***® indicates that this paper has been cited over 510 times since 1961.]

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"The search for a classification had been on since 1950, based on selecting some 'more fundamental' particles out of the known ones. The rest would then be composites. Fermi and Yang[1] had suggested the proton p and neutron n and their antiparticles p, n as basic, and Sakata had added a A hyperon with a unit of strangeness. The " + or *a"*. hyperons, for example, were assumed to consist of (A pn) and (AAp) respectively, the. latter with spin 3/2. This had led the Sakata group in 1959-60 to use SU(3) as a symmetry of p, n, A.[2] I was not aware of that fact at the time.

"I was an Israeli Army Colonel serving as defense attache' to the London Embassy. I now had a year's leave, working at Imperial College under A. Salam for my PhD. He had suggested a good calculation but I was captivated by the classification problem. Salam warned me this was highly speculative. I used an abstract approach: could all known particles be plausibly fitted in representations of a Lie group of order two? I had abstracted this condition, observing that all reactions conserving strangeness and isospin appeared allowed in strong interactions. I checked systematically through Cartan's list, which yielded SU(3) and the octet assignment for baryons (p, n, A, Ó+, Ó°, Ó-, E°, I). Here I had spin 1/2 like p, n, versus the Sakata prediction 3/2. Later experiments confirmed 1/2. The seven spinless mesons fitted another octet, with one meson missing. Theory also required an octet of spin-one mesons. All this was experimentally validated within a year, mostly by the Alvarez group.[3]

"With baryons in an octet, could they themselves be composite? With H. Goldberg back in Israel we suggested the fundamental objects were 'thirds of baryons,' i.e., a proton would be made of three of them.[4] This would 'explain' SU(3). That paper is seldom quoted. It appeared before the physics community had really adopted SU(3) and the octet, as a result *of* the Omega-Minus experiment in 1964.[5] Cell-Mann and Zweig perfected the idea of a fundamental triplet (quarks) and happened to publish their papers in the wake of the Ù excitement.[6]

"Quarks have not been found in a free state to date but have been observed inside p, n. They are probably confined. SU(3) proved very useful beyond strong interactions, providing also a precise description of weak and electromagnetic interactions.[7]

"Originally, the paper had a detailed mathematical introduction. However when I heard from Salam that SU(3) had already been used by the Sakata team, I naively shortened my introduction. Luckily, I kept the explicit matrices for the particle families.

"After I had sent the paper to *Nuclear Physics,* we received Cell-Mann's (unpublished) draft with similar ideas. When my paper was returned with an angry letter from the editor complaining about single-spaced typing, I added a note about Cell-Mann's draft and an independent suggestion by Salam and Ward of the spin-one octet, based on the Sakata model.

"The Ù experiment so unambiguously confirmed this paper's theory that it became a paradigm upon which all further progress would be based (quarks, currents, color, charm, etc.), thus accounting for its frequent citation."

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4. **Goldberg H & Ne'eman Y.** Baryon charge and *R*-inversion in the octet model. *Nuovo Cimento* **27**:1-5, 1963.
5. **Barnes V E, Connolly P L, Crennell D J, Culwick B B, Delaney W C, Fowler W B, Hagerty P E, Hart E L, Horwitz N,Hough PVC**, **Jensen J E, Kopp J K, Lai K W, Leitner J, Lloyd J L, London G W, Morris T W, Oren Y, Palmer R B, Prodell A G, Radojicic D, Rahm D C, Richardson C R, Samios N P, Sanford J R, Shutt R P, Smith J R, Stonehill D L, Strand R C, Thorndike A M, Webster M S, Willis W J & Yamamoto S S**. Observation of a hyperon with strangeness minus three. *Phys. Rev. Lett.* 12:204-6, 1964.
6. **Gell-Mann M.** A schematic model of baryons and mesons. *Phys. Lett.* **8**:214-5, 1964.
7. **Cabibbo** N. Unitary symmetry and leptonic decays. *Phys. Rev. Lett.* 10:531-3, 1963.