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Chiral symmetry and effective field theories for hadronic, nuclear and stellar matter

Jeremy W. Holt [a,*], Mannque Rho [b,c], Wolfram Weise [d,e]

[a] Department of Physics, University of Washington, Seattle, 98195, USA
[b] Department of Physics, Hanyang University, Seoul 133-791, Republic of Korea
[c] Institut de Physique Théorique, CEA Saclay, 91191 Gif-sur-Yvette, France
[d] Physik Department, Technische Universität München, D-85747 Garching, Germany
[e] ECT*, Villa Tambosi, I-38123 Villazzano (TN), Italy

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ABSTRACT

Chiral symmetry, first entering in nuclear physics in the 1970s for which Gerry Brown played a seminal role, has led to a stunningly successful framework for describing strongly-correlated nuclear dynamics both in finite and infinite systems. We review how the early, germinal idea conceived with the soft-pion theorems in the pre-QCD era has evolved into a highly predictive theoretical framework for nuclear physics, aptly assessed by Steven Weinberg: "it (chiral effective field theory) allows one to show in a fairly convincing way that what they (nuclear physicists) have been doing all along... is the correct first step in a consistent approximation scheme". Our review recounts both how the theory presently fares in confronting Nature and how one can understand its extremely intricate workings in terms of the multifaceted aspects of chiral symmetry, namely, chiral perturbation theory, skyrmions, Landau Fermi-liquid theory, the Cheshire cat phenomenon, and hidden local and mended symmetries.

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* Corresponding author.
E-mail address: jwholt.phys@gmail.com (J.W. Holt).

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1. Prologue

This review covers a broad spectrum of mutually related topics, from the symmetry breaking pattern of QCD and the structure of hadrons to various facets of the nuclear many-body problem and to the physics of dense, strongly interacting matter as it is realized in the core of neutron stars. It is written as a tribute to Gerry Brown who pioneered and shaped these fields of research in his own very special style. Each one of the authors benefited greatly from multiple exchanges with Gerry, as senior collaborator over decades (M.R.), as postdoctoral fellow and frequent visitor to Stony Brook (W.W.), and as Gerry's former Ph.D. student in his later years (J.W.H.), thus representing three generations of researchers inspired by Gerry Brown's intuitive way of thinking.