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Pattern Formation and Turbulence in Convection, the Legacy of Henri Bénard.[1]

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Just over a century ago a 26-year young physicist by the name of Henri Bénard handed in his Ph.D. thesis, entitled *Les tourbillons cellulaires dans une nappe liquide*, at the Ecole Normale Supérieure in Paris. In a fluid layer with a free upper surface and heated from below he observed and studied remarkably regular hexagonal patterns. Here I shall attempt to trace the developments in nonlinear physics, and especially in fluid mechanics, that have evolved from Bénard's seminal experiments. As a result of the work of many, including Lord Rayleigh, Harold Jeffries (Sir Harold), W.V.R. Malkus and G. Veronis, and especially Fritz Busse (2000 Fluid-Dynamics-Prize recipient) and his long-term collaborator Richard Clever, a remarkably detailed understanding of the nature of convection in a shallow fluid layer between two solid horizontal confining surfaces and heated from below had been gained by the early 1970's. The bifurcation to convection is stationary and occurs at a temperature difference (in dimensionless form represented by the Rayleigh number R) and a wave number k that are non-zero (Rayleigh, Jeffries). The bifurcation is supercritical to a pattern of rolls (Malkus and Veronis; Schlüter, Lortz, and Busse). Above onset there is a finite range in the $R-k$ plane, delimited by several interesting instabilities, over which the rolls are stable (Clever and Busse). This region, known now affectionately as the "Busse Balloon", has been used during the last three decades to study both theoretically and experimentally numerous non-linear phenomena, including the role of thermal fluctuations near the bifurcation, the dynamics of pattern coarsening, various wave-number selection processes, spatio-temporal chaos, and spatially localized structures or "pulses". In somewhat more recent times the range of R has been extended up to 10^{14} times the critical value $R_c = \mathcal{O}(10^3)$ at onset and a richness of phenomena involving turbulent flows has been revealed and studied quantitatively. One of the particularly interesting issues amenable to study in this system has been the interaction between large-scale flow structures and the small-scale turbulent fluctuations; but there are many other aspects that have provided seemingly endless fascination for the researchers.

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