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Phylum Echinodermata*

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"…this highly diverse, successful, and ancient phylum." (Littlewood *et al.*, 1997)

Introduction

The Phylum Echinodermata, comprising approximately 7,000 living species, and 13,000 fossil species, is epitomized by the familiar sea star, a universal symbol of the marine realm. This distinctive group of animals may be briefly defined as possessing a skeleton of calcium carbonate in the form of calcite; a unique water-vascular system which mediates feeding, locomotion, and other functions; and a more or less conspicuous five-part radial symmetry. A closer look at some extant echinoderms will show that some taxa of sea cucum-

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bers lack calcite in their body walls, some taxa of sea stars have "outgrown" five-part symmetry and may have 50 or more arms, and many echinoderms show a more or less conspicuous bilateral symmetry superimposed upon a radial pattern. Fossil echinoderms can be even more puzzling, for some are decidedly asymmetrical, and others may lack evidence of a water-vascular system. Perhaps the only truly reliable taxonomic character of the phylum is that its members today are restricted to the marine realm.

Despite, or perhaps because of, their distinctive appearance and characteristics, the echinoderms continue to be of great interest to specialists studying higher levels of classification of invertebrates. The history of the phylum is fraught with misconceptions. Linnaeus (1758) did not recognize the echinoderms as a separate group, and placed the echinoderms that were known to him in his "Mollusca", a subdivision of "Vermes". Bruguière (1791) revived Klein's (1734) name Echinodermata—a short-lived independence for the group, for Lamarck (1801) referred the echinoderms to his "Radiata", where they stayed for several decades until finally Leuckart (1854) successfully established the Echinodermata as a distinct phylum. Over the past 160 years, progress on the higher classification of the extant and fossil echinoderms has been fairly steady, with such authors as Ludwig (1889–1907), Bather (1900), Cuénot (1948), and Hyman (1955) providing authoritative summaries of classification history. Given today's formidable flow of publications on higher classification of echinoderms, a one-volume summary *a la* Hyman's would be a monumental task for a single author!

The numerous authors who contributed to the Echinodermata volumes of the Treatise on Invertebrate Paleontology (Moore, 1966–1978) grasped the opportunity provided by the Editor, Raymond C. Moore, to revise the groups for which they were responsible, so that the 1960's became an era of great change in our knowledge of the phylum. At times, new and innovative classifications displaced the old, while for certain taxa the old arrangements won out, but not before exchanges of many letters among the experts had taken place. I was but a minor participant in the Treatise Echinodermata volumes (Pawson, 1966; Fell & Pawson, 1966a, 1966b), but my file of correspondence with Raymond Moore on various problems in the Echinoidea and Holothuroidea is very thick!

Publication of the Treatise volumes stimulated much research work, particularly on fossil groups. New and exciting approaches to taxonomy have resulted in a reassessment of most major groups of fossil and living echinoderms. Cladistic analyses of extant and fossil groups helped to reshape some major classifications, and Mooi and David's (2000 *et. al.)* extraxial-axial theory (EAT) provided a new framework for study of interrelationships. Within the past couple of decades, molecular analyses are offering powerful tools, especially in combination with morphology, with which to address long-standing problems. Thus, the past 40 years have witnessed upheavals in classification at the family, order, and even class level. In the past decade numerous important volumes have been published on the echinoderms, living and fossil. Some of the most comprehensive include: Candia Carnevali & Bonasoro (1999), Mooi & Telford (1998), Barker (2001), Jangoux & Lawrence (2001), Féral & David (2001), Kasyanov (2001), Heinzeller & Nebelsick (2004), Matranga (2005).

Despite the increasing attention received by to this phylum, there remain many major uncertainties and unresolved problems. I am not qualified to suggest solutions to higher classification problems. Rather, in the present paper I hope to highlight some recent research developments in extant and fossil classes. The references cited are not intended to be exhaustive; rather, it is hoped that they will lead the reader into the extensive relevant literature.

Echinodermata as Deuterostomes

The extant Deuterostomia ("second mouth") are usually defined as animals in which the mouth develops from a second opening in the embryo, opposite to the initial opening, the blastopore, of the rudimentary gut. In addition the coelom develops by enterocoely, or pouching from the primitive gut. Smith (2004b) noted that