Preface to the Series

Invertebrates surpass vertebrates not only in species number but also in diversity of sexuality, modes of reproduction and development. Yet, we know much less of them than we know of vertebrates. During the 1950s, the multi-volume series by L. H. Hyman accumulated bits and pieces of information on reproduction and development of aquatic invertebrates. Through a couple of volumes published during 1960s, A. C. Giese and A. S. Pearse provided a shape to the subject of Aquatic Invertebrate Reproduction. Approaching from the angle of structure and function in their multi-volume series on Reproductive Biology of Invertebrates during 1990s, K. G. Adiyodi and R. G. Adiyodi elevated the subject to a visible and recognizable status.

Reproduction is central to all biological events. The life cycle of most aquatic invertebrates involves one or more larval stage(s). Hence, an account on reproduction without considering development shall remain incomplete. With passage of time, publications are pouring through a large number of newly established journals on invertebrate reproduction and development. The time is ripe to update the subject. This treatise series proposes to (i) update and comprehensively elucidate the subject in the context of cytogenetics and molecular biology, (ii) view modes of reproduction in relation to Embryonic Stem Cells (ESCs) and Primordial Germ Cells (PGCs) and (iii) consider cysts and vectors as biological resources.

Hence, the first chapter on Reproduction and Development of Crustacea opens with a survey of sexuality and modes of reproduction in aquatic invertebrates and bridges the gaps between zoological and stem cell research. With capacity for no or slow motility, the aquatic invertebrates have opted for hermaphroditism or parthenogenesis/polyembryony. In many of them, asexual reproduction is interspersed within sexual reproduction. Acoelomates and eucoelomates have retained ESCs and reproduce asexually also. However, pseudocoelomates and hemocoelomates seem not to have retained ESCs and are unable to reproduce asexually. This series provides possible explanations for the exceptional pseudocoelomates and hemocoelomates that reproduce asexually. For posterity, this series intends to bring out six volumes.

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Preface

Being arthropods, the crustaceans molt to grow and/or reproduce. Of 52,000 species, >96% crustaceans brood their eggs on their body. Consequently, they share the available resources among intensely competing processes (i) growth including molting, (ii) breeding and (iii) brooding. Hence, they are unique among aquatic invertebrates and render the study of reproduction and development a fascinating field of research. Not surprisingly, many books are written but they are limited to one or another taxon or aspect of reproduction and development. This book represents the first attempt to comprehensively elucidate almost all aspects of reproduction and development covering from anostracan *Artemia* to xanthid crabs.

Commencing with resource allocation to reproduction, the second and third chapters display that the investment on generation time as a fraction of life span averages to 28, 48 and 85% in tropical, temperate and Arctic crustaceans. Consequently, the tropical cladocerans, for example, produce 10 times more neonates than their temperate counterparts. That their hallmark strategy of brooding embryos costs considerable time and resource investment is demonstrated by the fact that the egg shedding calanoids and penaeids produce 3-20 times more eggs than the brooders. A second consequence of brooding is the liability of the brooders to reproductive senescence. For the first time, the book has adduced adequate evidence to establish the fact that brooding gonochorics, parthenogenics and hermaphrodites of all taxons across Crustacea do undergo reproductive senescence. With inclusion of many species characterized by sessile, sedentary or slow motile groups, gonochorism in crustaceans is limited to 92%; the remaining 8% employ alternate sexuality of parthenogenic and hermaphoditism. To escape from inbreeding, parthenogenics sporadically or regularly produce sexual males and females, or intertwine hybridization and polyploidization. On the other hand, hermaphrodites employ sequential hermaphroditism or androdioesic mating system.

The fourth chapter explains that the same tissue types are involved in regeneration of the lost part(s) of chelar appendages and asexual reproduction of the externae in the exceptional hemocoelomate of the parasitic colonial rhizocephalan females. They are limited to a few tissues derived from ectoderm and mesoderm alone. Hence, the so called asexual reproduction in these rhizocephalans simulates more of regeneration than of agametic cloning of a whole animal.

The fifth chapter is concerned with cyst and their equivalents like the ephihippia and diapausing embryos/larvae. In *Artemia* cyst, protein synthesis and degradation are ceased, trehalose is used as metabolite, metabolism is depressed down to 500,000 times and the cyst can survive anoxia for four years. A number of environmental factors are known to trigger cyst hatching. However, even the most potent cue does not initiate hatching in all cysts in an egg bank. Hatching in batches is a crustacean trait. In brooded embryos, hatching is initiated by the mother with the release of a chemical substance. However, almost nothing is known on the mechanism, which controls cyst hatching in different batches.

Interestingly, collections of widely scattered information reveal that (i) the sex in crustaceans is genetically determined at fertilization and (ii) the presence of both male and female heterogametic sex determination mechanisms. The ostracods have explored employing numerically more X (X_1-X_{11}) chromosomes to determine the female sex and anostracans used B chromosome to determine the male sex.

Chapter seven provides an account of sex differentiation by endocrines and its disruption by endocrine disruptors, parasites and food. Unlike vertebrates, endocrine and spermatogenic functions are clearly separated into distinct androgenic glands and testes, respectively. In crustaceans, sex differentiation process is irrevocably completed on or before metamorphosis or birth. Juvenile hormone or its analogs induce(s) parthenogenic male production in cladocerans. But the ability of these chemically induced males to fertilize eggs remains doubtful. Limitation of food induces production of males in cladocerans but females in copepods. Specific alga induces direct development of females in protrandric hippolytids. For the first time, cymathoid parasites are recognized and designated as protrandrics and the other bopyrids as protogynics. Briefly, parasitism in bopyrids has retained sexual plasticity until their cryptoniscus larvae settle on the definitive hosts and also eliminated the reproductive senescence.

This book is a comprehensive synthesis of over 972 publications carefully selected from widely scattered information from 249 journals and 101 other literature sources. The holistic approach and incisive analysis have led to harvest several new findings and ideas related to reproduction and development in crustaceans. Hopefully, this book serves as a launching pad to further advance our knowledge on reproduction and development of crustaceans.

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