

Preface

Time is neither an entity nor a process and hence, cannot be measured and defined. In physical terms, however, the temporal measurement is observed in the form of the output from a clock – a mechanistic process that progressively counts the passage of time in seconds, minutes and hours. This in turn provides a calendar, which is a mathematical abstraction of ‘clock time’ over a longer period, e.g. day, month or year. In the biological context, time almost serves as the ‘sixth’ sense. All living beings have the sense of time and use it to sequence and restrict their most, if not all, biological activities to a specific time during the day and during a season of the year. Central to this is the evolution of an elaborate timekeeping mechanism(s), the ‘clock’ that keeps on ‘ticking’ and ‘telling’ an organism with great precision about the ‘correct’ time of day and time of year. Based on the temporal information coming out, we designate these clocks as the circadian (*circa* = about; *dian* = day), circannual (*circa* = about; *annum* = year), ultradian (shorter than the day) and tidal/lunar (periods matching the ocean tides and lunar day) clocks. The clock-driven measurable recurring processes are appropriately called as the circadian, circannual, ultradian and tidal/lunar rhythms.

Natural selection has operated in such a way that all rhythmic events occur synchronized (entrained) by external agents in the geophysical environment. In the natural environment, therefore, the rhythms are exhibited as daily, annual and tidal/lunar rhythms. The main agents (factors, cues) from the environment that synchronize (entrain) these endogenous rhythms to local time include the daily cycle of changes in the illumination, temperature, food availability, social factors, etc.

The endogenous timekeeping is achieved through a layered system of the organization and control, which consists of the molecules, cells, tissues, circuits and networks. These layers add to the complexity of orchestration of body rhythms to a concerted action in synchrony with changes in the local environment. Thus, unless carefully operated in sync with the external world a species or individual inhabits, there are heightened chances of the disruptions and hence dysfunctions; anything can go wrong anywhere. The self-sustained and robust timekeeping mechanisms, therefore, exhibit interesting individual and species between the

habitats and latitudes, since each individual and species can define its own relationship with the environment it inhabits.

The time perspective in biology was fully recognized some 50 years ago in a Cold Spring Harbor symposium. Since then, the study of biological timekeeping – called chronobiology – has evolved as a truly interdisciplinary science and attained a global appeal, expanding from the biodiversity, physiology and genetics to health issues, fitness and survival. Spectacular advances have been made in the field of chronobiology during the last years, with contributions by some of the best brains drawn from different disciplines, viz. biology, chemistry, physics and medicine. Much effort has been directed towards deciphering the clock mechanisms, particularly the cellular and network interactions within and between individuals as well as with the environment. In the last decade, there have been significant advances in our appreciation of the role of clocks in metabolism, sleep, cognition, immune functions and diseases. Increasingly evident is the application value of the biological clock in the human society, especially among the people working at ‘unnatural’ times of day (e.g. shift workers). Intensive research has shown associations of several chronic disorders and lifestyle-related diseases with disruptions of the circadian rhythm or the clock networks. No wonder, with outlets open 24×7 , eating at the wrong time or consuming food more than required by frequent eating can lead to obesity and in turn have consequences on fitness and health. The ever-growing list of diseases linked with clock disruptions includes obesity, diabetes, cardiac diseases, depression and cancer. Also, the timing and duration of therapy, called chronotherapy, have been found critical in determining the efficacy of drugs.

The present book treats the organization and importance of clocks in animals and humans alike and covers significant aspects of the timekeeping mechanisms in both the groups. The book attempts at answering questions related to the ecological and evolutionary implications of the clock. I set out clear goals when I conceived the idea of bringing out this volume. Besides clearly outlining the history, origin and basic features of the clock, the book comprehensively includes the organization of clock system in *Drosophila*, fish, amphibia, reptile, birds and rodents, to present a complex and diverse nature of the timekeeping mechanisms among different animal groups, as this is generally not available in recent volumes on the subject. Secondly, the book includes topics that characterize rhythms in human and deal with the potential applications of circadian rhythms to health issues, including the metabolism and immune functions. Thirdly, a few chapters deal with the mechanism(s) of time generation and synchronization to the environment, both at cellular and molecular levels. A small section deals with the role of melatonin in regulation of daily and seasonal functions in animals. Finally, the book details on seasonal timekeeping mechanisms, with emphasis placed on genetic and epigenetic regulations of physiology and behaviour. Overall, the book tends to cater the needs of advanced undergraduates, researchers and professionals engaged in the field of chronobiology. I have avoided duplications or curtailed texts on topics that have been covered in important books published during the last 10 years, unless a particular topic was important for the present book and required a fresh look at this time.

A well-known expert in the area has authored the chapter. When presenting a state-of-the-art account, the text provides a consistent thematic coverage with adequate illustrations and feeling of the methods of investigations to arrive at the statements. The citation of references within the body of the text adequately reflects the literature as the subject is developed. Full references at the end of each chapter are useful to a reader interested to go deeper into the subject.

I am grateful to all the authors who have very kindly agreed to be part of this book. They have been extremely cooperative all the time. However, I am fully aware that the present volume of *Biological Timekeeping: Clocks, Rhythms and Behaviour* by no means can be considered as a full account of the subject. And I am solely responsible for the sins of omissions and commissions that are inevitable in an endeavour of this nature.

Undertaking such a mammoth task along with regular teaching, research and many other responsibilities requires immense goodwill and huge support. I have no hesitation that a strong team of doctoral and postdoctoral students during more than three decades of my professional career has made it possible by enabling me to learn more and find newer ways to overcome the challenges. I have very sincere words of praise and acknowledgement for all of them. Also, I have excellent friends both in India and abroad, who have full trust in me and always have encouraged my academic pursuits. My whole family supports me in whatever I do in the academics, and I am sure they would derive some satisfaction that their constant support has allowed me to produce something worthwhile. Finally, Springer (India) Pvt. Ltd., in particular Dr. Mamta Kapila and her excellent team, deserves special appreciation for the full support they have extended all along in bringing out the present volume.

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