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Time flies like an arrow: Fruit flies like a banana☆

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Summary The 2014 Beilstein Bozen Symposium on *Chemistry and Time* was as diverse in topics, and hence as difficult to summarise in a few words, as all of its predecessors. We can all agree, however, that time is fundamental in all of science, affecting everything we do, and everything that happens in a chemical system, and so the diversity of topics is just a reflection of reality, and the Symposium in Prien left all of its participants with the feeling that they had learned something interesting and novel.

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Introduction

The title of the article is, of course, a play on the different meanings of the word *flies*, but it is more relevant to note that the opening word, *time*, has a variety of meanings as well, and has many diverse effects on physical, chemical and biological processes. It spans 25 orders of magnitude, from the 14 billion years of the astrophysicists to the femtoseconds (Chapman et al., 2011) of the crystallographers, and at every stage on the scale it is relevant to chemistry and biology. Much of this range was discussed during the 2014 Beilstein Bozen Symposium on *Chemistry and Time*, and it is not easy to summarise it all succinctly. One thing is clear, however: everyone who was lucky enough to participate in this symposium went away having learned some interesting information that they did not know before.

Biological time

Clocks and life

In his lecture Tim Clark described biology as ''stuff happening in dirty water'', but those of us who are biologists like to think of biology as more interesting than that implies, and time is no less important in the timescales that we notice in living systems as it is for the millions of years considered by geologists, astrophysicists and evolutionary biologists, or the femtoseconds that allow structures to be determined before they disintegrate. I shall start by thinking about the most familiar time scales, from seconds to days to years that define our everyday lives. All animals are profoundly influenced by time, and humans are no exception. We live by the clock, but we sometimes forget the underlying physiology, thinking that we can ignore the problems created by variations in day length during the year, as well as those — more obvious — caused by moving through several time zones in a few hours, made easy by modern air travel.

Our physiology did not evolve to experience artificial light during the periods we wish to be awake, but research on the nature of sleep and the effects on it of an artificial clock that ignores changes in day length has been surprisingly sparse. Despite the alarming evidence of widespread pathologies due to sleep-related problems, with costs believed to approach 1% of gross domestic product in some countries, sleep research is barely in the top 100 of the funding categories of the US National Institutes of Health (Roenneberg, 2013).

Circadian rhythms

Research into the nature of the circadian clock has, of course, been applied for many years, at least since the classic review of Hess and Boiteux (1971), and pursued subsequently by others (Goldbeter, 1996). However, these studies have been designed primarily to understand the biochemical mechanisms of circadian rhythms, for example, the role of cycling of the monosaccharide β-*N*-acetylglucosamine in them (Ma and Hart, 2014), as described by Gerald Hart, or the structure and function of cryptochromes, proteins that regulate clock genes (Schmalen et al., 2014). Akhilesh Reddy described how some other proteins, the peroxiredoxins, are closely related to non-transcriptional mechanisms that contribute to timekeeping, and their circadian oscillation is conserved across the whole range of life: bacteria, archaea and eukaryotes (Edgar et al., 2012). He explained how this is related to the different effects of the same nutritional intake at different times of day on human body weight: better to consume calories at breakfast than the same amount at dinner.

Sleep research

By contrast, the effects on health of interfering with rhythms has been given much less attention, despite the observation that shift work, for example, can greatly increase the likelihood of cancer (Knutsson et al., 2013), or that sleep disturbances are associated with early Parkinson's disease (Breen et al., 2014). Till Roenneberg described the human sleep project (Roenneberg, 2013), which is designed to fill in some of the gaps: it uses a questionnaire to collect information from more than 150,000 respondents around the world about their sleeping habits, in the hope of obtaining a better understanding of the relationship between sleep and health. A particularly interesting part concerns the Quilombos, an Afro-Brazilian population that is genetically fairly homogeneous, but very diverse in terms of living habits: some live