Trying to beat the clock

Rhythms of Life: The Biological Clocks that Control the Daily Lives of Every Living Thing
by Russell Foster & Leon Kreitzman
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Till Roenneberg

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The dark side of shift work: night workers suffer because they can't fool their circadian clock.

"We eat when we are hungry, sleep when we are tired." These are the first words of a new book that describes one of the most fascinating subjects of modern biology — the biological clock. In the triviality of these first words lies one of the reasons why science has neglected this subject for most of its history: it seems so banal that we get up when the Sun rises and go to bed when it sets.

Although Jean-Jacques de Mairan discovered in 1729 that daily rhythms in plants are independent of the Earth's light–dark cycle, the scientific birth of clock research lies in the middle of the nineteenth century. coinciding with the invention of the light bulb. One could argue that Thomas Edison is the godfather of circadian research, because it was with growing independence from sunlight that scientists became aware of the fact that the daily structure of our behaviour has a life of its own. Circadian research picked up pace throughout the twentieth century, culminating in the discovery of clock genes around the turn of the century.

In their book *Rhythms of Life*, Russell Foster and Leon Kreitzman succeed in walking a tightrope — although clearly understandable to the lay reader, the detailed description of the biological clock will also be fascinating for scientists. The authors take readers on a captivating journey, walking them through the history of clocks, both mechanical and biological, and guiding them through the spinney of terminology. They lead them on a hunt through tissues and cells, molecules and genes, in a search for the location of the biological clock, and for the parts that make it tick.

When shielded from the outside world, the biological clock runs free at its own pace. Depending on the organism and the individual, the period is slightly shorter or longer than 24 hours (hence circadian, meaning 'about one day'). The circadian clock is synchronized to the 24-hour daily cycle by environmental signals or *zeitgebers* (a German term meaning 'time givers'), predominantly by light.

For most of us, light is the basis for viewing the world, yet there is more to light perception than just vision. This discovery is one of the most fascinating achievements of chronobiology, and Foster is the pioneer who made it possible. Vision relies on local contrast, and requires high spatial and temporal acuity. But the circadian clock, and probably many other biological functions, simply needs to detect whether there is light, and how much. In the course of deciphering the light input to the circadian clock, a completely new light-sensing machinery was discovered. The clocks of mice whose retinae are completely devoid of rods or cones, which are needed for vision, still respond perfectly to light signals. It is a shame that the coverage of this fascinating story is kept relatively short — I hope that this will be the subject of another book.

After explaining the biological basis for daily timing, Foster and Kreitzman bring us back to civilization. With the help of light and the biological clock, our behaviours and all of the functions in our body are placed at the 'right' time of day. Humans are day-active, and as such have specialized senses (and a colourful appearance) that we share with other day-active animals — these characteristics are different from those of night-active creatures. But are we really safe from being active at the wrong time of day?

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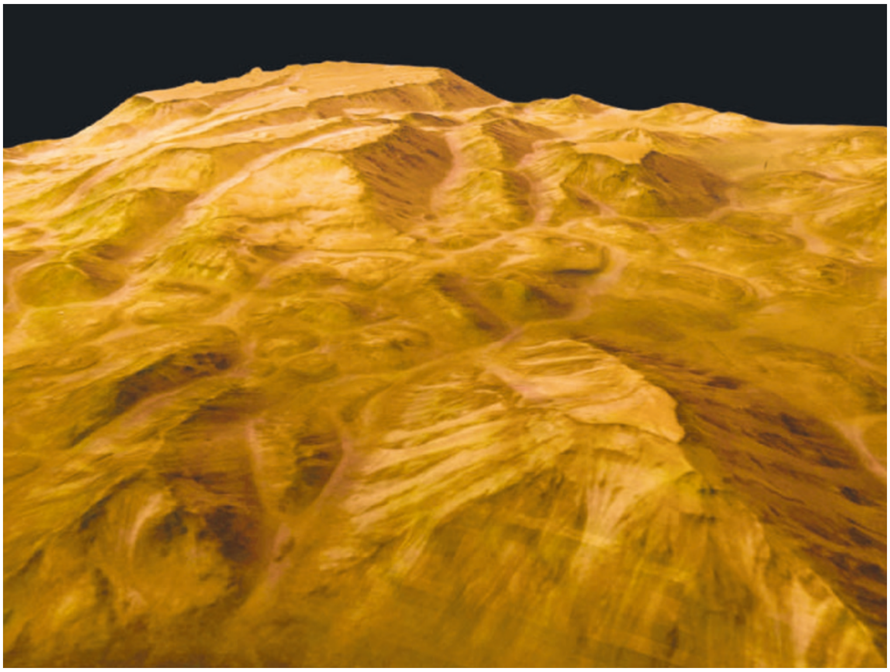
Science in culture

Mars the sublime

The first images from the Mars Express orbiter highlight the universal beauty of the wilderness.

Martin Kemp



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This image of Valles Marineris from Mars Express shows that barren landscapes can be beautiful too.

"It's just so beautiful as well as awe-inspiring… It's art and science and beauty and exploration all mixed up together". John Murray of Britain's Open University, one of the international team involved in the European Space Agency's current mission to Mars, is speaking about the first images to be produced by the High Resolution Stereo Camera (HRSC) on the agency's Mars Express orbiter. Looking at this view of the Grand Canyon of Mars (Valles Marineris), it is easy to see why.

But why should we find beauty in the barren topography of a planet that is so hostile to life? The answer lies in the interplay of our conditioned response to particular kinds of sublime landscape and the aims behind the image's generation. Our appreciation for painted landscapes that are awesomely terrible, rather than pastorally comforting, was the product of the Romantic imagination in the eighteenth century. Edmund Burke's *Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful* in 1757 set the tone.

Wilderness, particularly the vast tracts of newly explored territories in North America, became a source of aesthetic pleasure. James Fenimore Cooper's book *The Last of the Mohicans*, from 1826, plays out its tragic narrative against great vistas of mighty mountains, high plateaux and deep valleys. Our primitive and fundamental emotions seem to be more naturally expressed in savage topographies than in the artificial enclosures of cities.

The rhetoric of the sublime has long been integral to the imagery of the planets. Mars Express now presents us with images of the martian surface that are analogous to the aerial views on postcards that we might buy on a visit to the Grand Canyon. But the new pictures are not simply the high-tech equivalent of high-quality snapshots. We are witness to a superbly contrived visual model, the realism of which arises from the complex synthesis of the various data collected by the HRSC.

The data are the product of a 'linescan' camera that exploits the highest levels of optical and digital sophistication. It works with nine independent image strips, each of which consists of 5,184 light-sensitive cells, orientated perpendicularly to the flight direction. Three of the channels register red, green and blue, and another is sensitive in the near-infrared range. Three strips record photometric measurements, and two are dedicated to stereo information, to bring about the complete three-dimensional modelling of the planet's surface in full relief. Additionally, the data are read out at variable frequencies to accommodate the ground velocity of the orbiter.

The HRSC's resolution of up to 10 metres per pixel from an altitude of about 260 km, the closest that Mars Express gets to the martian surface, is supplemented by a Super Resolution Channel, which produces more detailed pictures, of up to 2.3 metres per pixel. The former produces reference locations for the latter, just as we need maps of varied scales when we move from cross-country roads into the dense grids of cities. The issue of resolution is crucial to the geological analyses that are the central goal of the explorations of Mars. Whatever detailed data might emerge from the Mars landers, fundamental judgements must be made on the basis of the gross topographies of the martian mountains and valleys seen in such images.

One attraction of the sublime landscapes that were painted around 1800 was that the grand topographies bore witness to the vast and ancient processes that shaped our planet. The geology of Charles Lyell and the visions of artists spoke the same language of huge transformation. When we look at the latest pictures of the dramatically scarred surface of the red planet, we bring to them the baggage of our aesthetic predispositions, to which scientists and non-scientists alike are powerfully subject.

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Modern man has created an indoor society, efficiently buffering environmental changes and, at the same time, choosing sustained dimness. Outside light intensities range between 10,000 and 100,000 lux (depending on cloud cover), whereas inside light rarely offers more that 100–400 lux. So the strength of the *zeitgeber* light, which is so important in synchronizing our biological clock, has decreased enormously as a result of industrialization. Humans have successfully conquered every available biotope, and the independence from sunlight now allows us to conquer every temporal niche of day and night.

We experience the consequences, for example during shift work or jetlag. Over millions of years, our biological clock has learnt to interpret that we experience the brightest light during the day, independent of when we are active. But the biological clocks of shift workers (some 20% of the working population in the West) compare the dim light during the night shift with the bright light of day, and refuse to be fooled. As a result, shift workers and travellers across time zones eat (and work) when they are tired and sleep when they are hungry.

We know that our industrialized lifestyle has many consequences. Living against our biological clock and shielding ourselves from daylight may be among the most important. It is time that the profound knowledge of clock research reaches everyone in our society. This book does an excellent job in this campaign. ■

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