Life's Ratchet

Life's Ratchet, by Peter M. Hoffmann, is an intriguing book. After a slow (but necessary) introduction, the book gets rolling. It is a pleasure to follow the author's prose and ideas. It is the kind of book you can take on an airplane or read leisurely in the evening. It presents a historical perspective of how the physics (and partly the chemistry) of molecular motors has developed, and combines that with a wealth of recent information about what we know of the microscopic physics of molecular motors. The subtitle of the book could perhaps be "A physicist's perspective of the workings of life".

The author's approach is simple, but not simplistic. In a famous joke, a wealthy playboy hires an economist, a biologist, and a physicist to win horse races. The economist devises a system of incentives for the horses. Several horses die of starvation and the playboy fires him. The biologist proposes a breeding plan extending over 200 generations and is immediately fired. Finally, the physicist explains that he has worked out the perfect solution: "First assume the horse is a sphere in a vacuum". Throughout the book, the danger of devising how to win the Kentucky Derby with a spherical horse is skirted, even courted, but elegantly avoided.

Entropy and the Second Law of Thermodynamics are truly at the heart of the physics of molecular motors. Violating, or better not violating, the Second Law in processes that reduce entropy is illustrated beautifully. Refrigerators produce a local reduction of entropy, but globally increase it. I would have loved to see the discussion linked more deeply to the efforts of chemists to develop artificial Maxwell's demons.

In every chapter, it is easy to find food for thought. Even on those occasions when I would beg to differ with the author, as on some aspects of the presentation of free energy, or when Latin is used instead of Greek, as in the case of the title of Aristotle's book *Περί ψυχῆς*, which is called *De Anima* (although I then discovered that this is an accepted name for the book in the *Corpus Aristotelicum*). And there are many genuine gems well worked into the text, as when the author explains why cherries burst open after rain, or when he explains entropy evolution using the example of the late-night thief who robbed him of ten dollars.

There are a couple of topics in the book that could have been treated in greater depth. The section entitled "Cows and quarks" begins to explain how, using theory, one could make a long and roundabout connection between these two types of entities. The chapter is a start. Time-scales and length-scales are the true issue here. To justify models that explain phenomena occurring in certain temporal and spatial dimensions requires models that are developed for smaller scales and "perceive" these scales as averages. We need models to predict these averages. Then we can build on them to construct models for larger scales. A simple case in point is the description of chemical bonds as classical harmonic oscillators, as in the relationship $V(r) = {}^{1}\!/_{2}\, k\, (r-r_0)^2$.

This electron-less description of the bond is accurate, despite the fact that we know that electrons are all that matters to make chemical bonds. The model is sound because it is based on the Born–Oppenheimer approximation, another model that we understand very well. Born–Oppenheimer allows us to calculate the expectation value of the electronic energy $V(r)$ for any value of r and then "forget about" electrons. Three quarks form a proton, protons and neutrons form atoms, atoms form molecules, thus going up and up and up until we get to the cow—or better if we do not, since we miss the understanding of some of the scales that reach up to the cow.

What science and society need is to bridge the gap by developing new schemes similar to that filled by statistical mechanics, something that systems biology is only starting to broach. As an example—and only as an example—we do not have first principles models that explain the state and the evolution of DNA. How and why codons AUA and UGA previously coded for methionine and tryptophan in human mitochondria and now code for isoleucine and "stop". The long-standing proposal that changes of coding should be preceded by the loss of the codon and its later reappearance is satisfactory, but hardly on the same level as predictions made for molecules by quantum mechanics or statistical mechanics.

In a book of this length and impact, it is only natural that one occasionally feels that the author has an axe to grind, for instance when he discusses the enormous contribution of Mayr to biological sciences. However, the comments are gentle and even humorous.

I enjoyed reading the book and I strongly recommend it. Would I give it to my son? The answer is an emphatic YES. I would also add: SON, come back when you are finished, because we need to talk, since a chemist's view of what are the inner workings of life is somewhat different from that of a physicist. And this is what makes lived life and science interesting.

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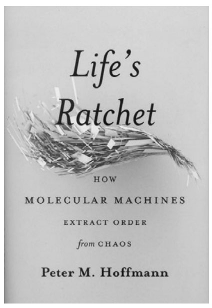

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