Foreword

Claiming to be intelligent is bold. The materials described in this book are actually somewhat less ambitious; they respond in an interesting way to an external stimulus: a field, a change in pH, a pulse of light, a temperature jump. I would tend to call them "sensitive" rather than "intelligent". But they have been invented, and improved, by highly intelligent scientists, and this shows in this book.

Assume, for instance, that we wish to make an artificial muscle from a chemosensitive gel. A great man (A. Katschalsky) started this game, exposing carboxylic acids to protons, converting the gel to a neutral, more compact form. But he immediately realised that cycles (hydrochloric acid/soda) would accumulate counterions, screen out the electrical interactions, and kill the muscle. He then used a clever ion exchange ($Na^{+} \rightarrow Ca^{++}$) that eliminates this form of fatigue. But he still could not solve the problem of time constants: bringing an ion, and contracting a gel, requires diffusion processes that are very slow for macroscopic samples. This is lucidly discerned in the present book. One way out is to operate with units of diameter below one micrometre. Another approach would be based on two interpenetrated networks – one elastic, and the other electrically conducting, bringing the required ions locally. But this is science fiction: to have a second network both flexible and chemically robust seems extremely difficult.

This "local feeding" problem is the heart of the matter: what the striated muscles of vertebrates achieved is local feeding of energy by ATP *all along* a myosin/actin structure.

In fact, this observation makes me doubtful about most artificial muscles based on nafions + water + ions: the ions are driven by an external voltage V ($\sim$1 V); the energy gain that this gives them when they move by one pore size d is only $eV\, d/L$ (where e is the unit charge, L is the sample thickness). Because of the factor $d/L \sim 10^{-5}$, this can never compete with myosin, which gains $\sim 10^{-2}$ eV per jump by burning ATP. But, again, the best approach to these difficult questions is to read the present book.

There is also an interesting hope with gels doped by ferrofluids, and the corresponding experiments are nicely described here. I am not sure, however, that these gels can compete with a naïve system, where a small cylinder of permanent magnet is attached to a rubber stem. (The permanent magnet leads to much higher forces than ferrofluids.)

These random remarks illustrate (I think) the difficulty in achieving industrial materials that can produce large stresses (1 atm) with a relatively fast response (1 s): furthermore they must not heat up too much. And they must be robust (chemically and mechanically); ultimately they should be not too expensive. This list of duties is somewhat frightening. But I am convinced that some young researchers will find answers – and that they will previously read this book, as a starting point. Thus, I do congratulate the editors for their vast collection – covering so many sectors of physics and chemistry.

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