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EDITORIAL

Electrochemistry—past, present, and future

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The year 2011 has been proclaimed by the United Nations as *The International Year of Chemistry*. This is a condign occasion to contemplate the role which electrochemistry has played in the formation of the modern world and to speculate how it might influence the future development of the planet. This topical issue of the *Journal of Solid State Electrochemistry* is therefore offered by the global community of electrochemists as a contribution towards the analysis of the scientific pathways from the past to the future.

Science is a complex edifice built from a vast number of observations and data, but held together by a much smaller number of concepts and theories. Although science is *man made*, its growth is a self-organized process which is only *marginally* affected by the actions of individuals. This idea might not please politicians, who imagine that they can steer the development of science according to their wishes (or their philosophies), but science continues to develop in surprising and unexpected ways. Indeed, to understand the development of science remains an unsolved problem, on one side to see what *can* be affected by man and on the other side–perhaps even more important–to see what *cannot* be affected by man.

Science, art, and religion are three of the ways by which human beings struggle to interpret the outside world. Besides theories, science also contains discoveries and inventions; a discovery being the finding of something that exists, and an invention being the making of what can be realized. These connections to the real world distinguish science from art and religion, where reality is experienced in a more subjective way. If Shakespeare had not written Romeo and Juliet, nobody else would have written it in quite the same way; whereas if Einstein had not initiated the theory of relativity, quite likely, one of his contemporaries would have produced something very similar. This communal character of science does not mean that the development of science is completely pre-determined, however. The historical path of events is certainly affected by social circumstances and by individual quirks of character. This is particularly noticeable in the *language* of science, which is strongly affected by its human creators.

Scientific theories are confident explanations of the connections between very large numbers of data or events. From these explanations, unknown data or events can be, or already have been, predicted in detail. However, as newer and more accurate data are acquired, it sometimes happens that existing theories are found wanting. For example, anomalies may come to light that have previously eluded detection and which cannot be dismissed as experimental errors. At these crucial moments in history, new theories must be developed to accommodate the aberrant data. In retrospect, the development of each new theory is usually presented by historians as a logical "next step." But, in prospect, the development of a new theory almost always appear to contemporaries as flawed, or even unnecessary,

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because the existing theory gives the impression of being sufficient unto the facts.

Why is it possible to improve scientific theories? Why are not they fixed for all time? The short answer is that scientific theories are "underdetermined." For example, one reason that scientific theories are underdetermined is that they would require an infinite amount of data to exclude all possible exceptions to them. Another reason is that algorithms for compressing data into theories are not themselves part of the data. For both these reasons, the generation of new scientific theories remains a creative act outside the process of acquiring and processing data. This explains why scientific theorizing cannot be automated. A collection of data, plus a set of logical principles, is simply not enough to predict the final form of any scientific theory. Something important is missing—in particular, the *hidden rules* are missing that determine the final form of the theory. The goal of the historian of science is to find these out.

The situation may perhaps be likened to that confronted by Noam Chomsky during his studies of the acquisition of language by young children. In all human cultures, children rapidly learn the language of adults, based on a meager vocabulary and a complete absence of formal training in logic or grammar. Yet, within a few short years, they are able to form an indefinite number of complex, grammatically correct utterances. Chomsky realized that children were using a set of hidden rules that were somehow "programmed" into their brains. Furthermore, since children learned whatever language they were presented with, it was clear that the hidden rules were common to all languages. For Chomsky, therefore, the central task of linguistics became the discovery of the missing rules. Despite its importance to the future progress and well-being of mankind, the analogous problem in physical science remains a completely open question. *We have no idea how scientists arrive at new theories*, or what hidden rules they are employing to do so. The illuminative spark of a new idea remains largely a mystery; although, in some cases, one is able to relate that spark to something existing in the mind of the discoverer far away in other areas of knowledge or experience, needing a psychologist to understand the inner relation. Of course, no one imagines that scientists are "programmed" for the development of scientific theories in the same way that children are "programmed" for the acquisition of language, so we must seek an explanation elsewhere. Where should we look? Possibly the "hidden rules" of science are somehow delivered by social and political influences in the environment in which scientists live and work; or maybe, they are encoded in their scientific heritage and tradition. In order to gain some insight into these mysteries, we recently asked leading, successful scientists in electrochemistry to tell us what they thought about the past, present, and future of their particular areas of specialization. Their multifarious responses are presented in this special issue of the *Journal of Solid State Electrochemistry*. We hope you find the articles interesting and informative; we certainly did. Are there certain working conditions that generate creative activity? Are there certain methods of innovating that can be learned? Are there certain areas of research that are ripe for plucking? At present, we just do not know the answers to these questions, but it seems reasonable to suppose that careful analysis of the pathways of scientific discovery will one day provide a solution. In the meantime, the memoirs found in the following pages may be considered as a first attempt to scale a very tall ladder.