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Editorial

Bioelectricity: A Quick Reminder of a Fast-Advancing Discipline!

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Bioelectricity is emerging rapidly in several areas of life sciences, medicine, and bioengineering, as highlighted in an excellent recent overview by Schofield et al.[1] It is rather surprising, therefore, that the Oxford Learner's Dictionary does not (yet) have an entry for bioelectricity! The Britannica defines it (rather simplistically) as ''… the generation or action of electric currents or voltages in biological processes.'' In fact, there is a lot more to bioelectricity than the Britannica definition. The field has suffered historically because ''electricity'' is physics and that can be a scare word for a lot of people involved in biological sciences. In fact, bioelectricity is centered on some of the most fundamental laws of nature and it is right in the core of our existential being. Without it, a DNA molecule could not stay together, and hydrogen and oxygen could not form water! Every cell in our body has a membrane potential equivalent to a voltage gradient of some 10,000,000 V/m, a massive force that many proteins therein will feel. Even red blood cells that do not have nuclei possess a membrane potential. So, it seems a cell can exist without genetic material but not without bioelectricity!

So, what is ''bioelectricity''? The short answer is a lot of things (not forgetting biomagnetism). The process is two way:

$$\text{ELECTRICITY} \leftrightarrow \text{BIOLOGY}$$

Living things, plants and animals—from bacteria and protozoa to mammals—generate and use electricity (ions and electrons) to perform a huge range of processes essential for life. These include production of energy within the mitochondria of individual cells to communication within cellular networks enabling our hearts to beat and our nerves to sense the environment (internal and external). Bioelectric signaling enables us to feel pain and take evasive action, if necessary, to survive. In fact, the role of bioelectricity extends well beyond these classics. Embryonic development and patterning, including stem cells, as well as the functioning of our immune system, and ''wound healing'' (in plants and animals) depend on coordinated bioelectric signaling across groups of cells.[2] In those cases, bioelectricity is not just a mechanism but is a true computational medium that underlies information processing. Indeed, this is the ancient trick, discovered by evolution, which later became speed-optimized as nervous systems. Bioelectricity also manifests itself in metabolism and homeostasis in the form of redox potentials and electron transfer between key molecules within cells. Naturally, when the body's bioelectricity goes wrong disease will follow. Again, this is well known to occur in pathologies such as epilepsy and cardiac arrythmias. More surprising are various autoimmune diseases, diabetes, and cancer.[3]

Less known or appreciated is how biology is employed to generate electricity—''industrial bioelectricity.'' At a rather basic level, residual biomass can be used to produce electricity. We highlighted some of these in the last issue of *Bioelectricity* giving examples of Brazil and Cuba. More ''high-tech'' is use of ''microbial fuel cells'' that exploit the bioelectricity of bacteria to convert organic waste material into electrical energy and are carbon neutral.

Then, there is a whole world of ''bioelectronics.'' At the classic end, techniques such as electrocardiogram have been in clinical use for decades. More recently, electroceutical procedures are increasingly entering the clinic. Thus, deep brain stimulation using implantable electrodes can be used to treat late-stage Parkinson's disease, and vagal nerve stimulation is used in treatment of depression, epilepsy, inflammatory syndromes, and multiple heart conditions. All this is possible without the use of drugs and is benefitting greatly from the development of new nanomaterials that can interface electrically with living tissues. Also, in surgical practice, detection and analysis of tissue bioelectricity can be used to determine whether to operate or not, and to define margins during the surgery. Finally, ''precision medicine'' (what used to be called ''personalized medicine''), the future of medical care, is benefiting from the specific bioelectric properties of individual patient's tissues, including in clinical imaging.

This editorial is meant to be a quick reminder of the wonders of bioelectricity and its immense potential in improving quality of life both directly through life sciences and health care, and indirectly through the economy. Our journal *Bioelectricity* aims to represent and promote this fascinating

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field and help fulfil its potential in the best possible way. We look forward more to sharing the excitement of this mission with our contributors and readers.

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