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Editorial

A New Phase in Applied Biology

Zdenko Machala[1] and Matthew J. Pavlovich[2,*,@]

We might think of plasma as what makes a flat-screen TV work. Maybe we learned that plasma is the fourth state of matter or have heard it described as an ionized gas. In reality, plasma is all of those things and much more: it is a highly energetic state of matter, with constituent particles that can reach tens of thousands of Kelvin. It contains a wealth of fascinating chemistry, including not only ions but also free electrons, photons, and radicals. It is the most abundant phase of matter in the universe, accounting for most of the mass of any given star, but it is also present terrestrially in lightning, neon signs, spark plugs—and, yes, flat-screen televisions.

Plasma biotechnology and plasma medicine is a nascent field that brings a revolutionary approach to healthcare by applying non-thermal (near-room temperature) versions of this phase of matter to various prokaryotic and eukaryotic cells, animal and human tissues, and even humans *in vivo*. Gas plasmas generate various reactive neutral and charged particles, as well as photons and electric fields. These are known to kill microorganisms for disinfection and sterilization, and they are beginning to play vital roles in therapies such as treating infected tissues, wound healing, and cancer treatment, among many others. It appears that the key roles in plasma-cell and plasma-tissue interactions are played by plasma-generated reactive oxygen species and nitrogen species (RONS). The same species and their multiple effects on biological systems have been widely studied in biology and medicine for decades, from the innate immune system's oxidative burst [1] to the antimicrobial and antitumor strategy of photodynamic therapy [2].

So the biggest advantages of plasma-based medical devices might be as tunable sources of exogenous reactive species for novel medical treatments, for example by easily controlling the dose and composition of active species. Fundamental challenges still lie in the relatively limited understanding of how these bioactive species interact with biological systems and how they are generated, chemically converted, and transported in complex liquid biological environments. Related emerging fields that require further research and will presumably provide a deeper understanding for plasma biotech and plasma medicine applications are plasma–liquid interaction, plasma interactions with cells or tissues, and plasma-enhanced chemical reactions in liquid.

This special issue of Trends in Biotechnology offers several state-of-the-art examples of these envisioned applications of cold plasmas in biotechnology and medicine. Direct exposure to plasma discharges or indirect exposure to plasma activated liquids is a strong weapon against pathogenic microorganisms in food production and processing (reviewed by Bourke and colleagues) and dentistry (Gherardi and colleagues), or against highly resistant microbial biofilms (Gilmore and colleagues). Carefully creating the right mixture of exogeneous reactive species by plasma treatments, and propagating those species in tissues, is a key challenge for fundamentally understanding these processes on the cellular level (introduced by Szili and colleagues), as well as in potential neurological treatments (Xiong). Numerical modeling of plasma chemical and transport processes brings valuable insight for designing appropriate experimental parameters of plasma sources and reactive species doses in plasma biotech (example provided by Babaeva and Naidis).

[1]Faculty of Mathematics, Physics and Informatics, Comenius University, 84248 Bratislava, Slovakia
[2]Editor, Trends in Biotechnology
[@]Twitter: @TrendsinBiotech
*Correspondence: tibtech@cell.com (M.J. Pavlovich).

Perhaps the most important unique point that supports the translation of plasma technology into industrial and clinical practice is its ability to produce RONS in high concentrations, on demand, at a desired spot. Examples range from treating tumors without harming nearby healthy cells (presented by Keidar and colleagues), to developing inexpensive distributed plasma sources for disinfection and wound healing suitable for places that lack conventional technologies and supply shortages, such as the developing world (Machala and Graves).

The still-exploratory yet dynamic state of the field may be what motivates and excites the researchers of multidisciplinary backgrounds working in plasma biotech and plasma medicine. The editors hope that readers will enjoy reading articles of this special issue, finding them as informative, helpful, and most of all, innovative and exciting.

References

1. Dougherty, T.J. *et al.* (1998) Photodynamic Therapy. *J. Natl. Cancer Inst.* 90, 889–905
2. Hultqvist, M. *et al.* (2009) The protective role of ROS in autoimmune disease. *Trends Immunol.* 30, 201–208