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Grow a Biological In Vitro Power Source on a Chip
Focus Group Summary

Summary written by:
Jessica Marshall, Graduate Student, Science Communication Program, University of California, Santa Cruz

Focus group members:
- Clemens Burda, Assistant Professor, Department of Chemistry, Case Western Reserve University
- Jennifer Cha, Research Staff Member, Department of Advanced Organic Materials, IBM Almaden Research Center
- Andrew Ellington, Professor, Department of Chemistry and Biochemistry, The University of Texas at Austin
- Mark Humayan, Professor, School of Medicine, University of Southern California
- Eric Jakobsson, Professor, University of Illinois at Urbana-Champaign
- David LaVan, Assistant Professor, Department of Mechanical Engineering, Yale University
- Jessica Marshall, Graduate Student, Science Communication Program, University of California, Santa Cruz
- Vijaykrishnan Narayanan, Associate Professor, Department of Computer Science and Engineering, Pennsylvania State University
- Richard J. Schwartz, Co-Director, Purdue University/Birck Nanotechnology Center
- Ali Shakouri, Associate Professor, Department of Electrical Engineering, University of California, Santa Cruz
- Peter Wolynes, Principal Investigator, Department of Chemistry and Biochemistry, University of California, San Diego
- Lynne Zucker, Professor, Department of Sociology, University of California, Los Angeles

Summary:

A handful of engineers, a pair of biologists, a couple of chemists, and a sociologist walk into a conference room. They've been told to solve a problem. One of the biologists says to the others, effectively, "This problem is stupid." Debate ensues and, in the end, two probably patentable ideas emerge, one posed by the dissenter.

The punch line of the story isn't laughable, but there is a punch line, nonetheless: diverse and intelligent minds stuck in a room together can do a lot in 8 hours.

This focus group was tasked with the problem titled, "Grow a biological in vitro power source on a chip," which implied to some group members a small-scale application, perhaps powering an implantable medical device.

But below the title, the problem description explained the goal as a technology that "should have the potential of improving the current costs to produce clean energy." This description implied to other group members that the aim was to devise a large-scale alternative energy source—replacing photovoltaics, for example—based on biology.

The researchers' first job, then, was defining the problem. They brainstormed broadly and discussed both approaches, initially responding to the skepticism offered by one group member that a small biological power cell was a “fundamentally non-doable, non-worthwhile problem.”

After initial brainstorming, the group began, somewhat inadvertently, by designing a system that achieved the latter goal of a large-scale biological power source. But by the end of the four 2-hour sessions, the group had design ideas for both applications.

In brainstorming and defining the problem, the researchers discussed power requirements for various devices and applications, and considered the unique attributes of biology and the nanoscale in energy conversion. In particular, group members considered the efficiency of photosynthesis—nature’s way of converting renewable, light energy into energy for growth. Photosynthesis is about 35 percent efficient at harvesting light energy (at certain wavelengths), but only about 1 percent efficient at converting that energy into glucose. By comparison, a modern photovoltaic panel is about 15 percent efficient. The group discussed possible applications that could accommodate the mediocre efficiency of photosynthesis.

The group also discussed unusual examples of energy generation in nature, including the electric eel, capable of producing a single 600-volt shock each hour. They discussed microbiological approaches to energy conversion, noting the disadvantage that microorganisms are evolved to use harvested solar or chemical energy for growth, not for surplus power generation. This makes such systems inefficient at external power generation, and can cause devices to foul as organisms multiply and form biofilms.

By the end of the first session, the group had discussed both ideas and sketched the architecture of a plan for a large-scale biological power source. The goal of creating a small, implantable, biological power source initially seemed intractable, because calculations suggested supplying enough power to run anything for a useful period of time was unlikely to be possible. Later, the realization that some devices have very low power requirements opened the door for discussion of this as a feasible approach.

The second session included a more detailed mapping of a solution to the large-scale power generation problem, making use of the expertise of several of the group members. With the initial concept—posed by the group’s initial skeptic—on the table, each researcher contributed to the solution. Leaving the initial debate behind, the group grew enthusiastic as ideas came together.

The group’s proposal circumvents the low efficiency of natural photosynthesis by converting light directly into electricity, eliminating a carbohydrate intermediate. The approach includes a strategy for expanding the spectrum of absorbable light beyond the normal (narrow) range allowed by photosynthesis.

One of the group members said of the proposed approach, “I think it stands scrutiny as an idea.”

Returning to the room the second day, the group discussed the small-scale power generation device. Their approach mimics power generation by the electric eel, which has long-fascinated scientists. Looking for information online, the group found Volta’s 18th century drawings of the eel’s electric organ and descriptions of surprising early experiments.

As the sixth hour in the room approached, the group allowed itself to joke about Star-Trek-like possibilities, including implantable eels, noting that if body piercing could take off, so could eel implants.

In the final session, late Saturday afternoon, conference keynote speaker Dr. Mark Humayan, of the University of Southern California, joined the group before his evening talk on the implantation and testing of an artificial retina in patients who had lost their vision. He brought medical expertise to the group, and his knowledge of power requirements for medical implants—which are much lower than the group thought—allowed the group to identify a feasible application for their small-scale power-generating device and to elaborate on its design. Again, enthusiasm grew as the group approached a solution, and the broad expertise of the researchers was impressive to see as they contributed to the solution.

Throughout the discussions, the group remained focused on quantitatively evaluating the feasibility of their ideas: back-of-the-envelope calculations flew fast and furious. The researchers recalled values from memory for biological and physical parameters—power requirements, dimensions, absorption spectra, process efficiencies—and fluently manipulated these numbers to estimate the limits of possible approaches and the requirements of possible applications.

Both environmental and health benefits exist for society by the development of these ideas. A biological power source would offer a clean and renewable energy source, avoiding fossil fuel consumption and the need for toxic materials used in photovoltaics and batteries. A small, implantable biological power source would be biocompatible and alleviate concerns about implantation safety and disposal of today's batteries, which contain metals and other highly toxic components; modern implanted batteries must be carefully encased before implantation.

Although the ideas generated by the group may seem fantastic, the researchers' commitment to assessing a minimum of feasibility was a key aspect of the discussion.

Indeed, one of the biologists summed up the session with his own punch line, satisfied that the group met at least one standard in their proposals:

"I don't think we've violated any laws of thermodynamics."

That's a good start.