Jan/Apr 2017 • No. 240

ESA Newsletter

Electrostatics Society of America - The Friendly Society

President's Message

Electrostatic Pollination:

The arrival of spring means travelling, flowering season, and for some, unfortunately, allergy season from air borne pollen. Nevertheless, for proper germination, pollination is highly essential and there are many different means of pollen transportation. Let us talk about pollination and electrostatics first and then talk about our plans to travel to the June meeting.

Wind, insects, bees, birds and water contribute to pollination in many different ways. Interestingly, research has shown the significance of an electrostatic force that develops between pollen clouds and/or the pollinator's body and the flowers. It has been observed that under fair weather conditions the clouds of pollen and/or pollinators like bees, insects, and birds possess positive charges whereas the plants possess negative charges; pollen/pollinators have opposite polarity from plants. Thus, accumulation of pollen on the surfaces of the pollinators and pollen distribution may enhance the forces of attraction between the pollinator's positively charged body and the negatively charged plants. As it is hard to distinguish between aerodynamic and electrostatic forces in directing the pollen towards the flowers' stigma, at present there is insufficient evidence about the role of electrostatics.

It was first suggested in the mid-seventies that electrostatic forces may be involved in the pickup and deposition of pollen by pollinators. Inductive charging causes movement of charge through plant tissues when a body of opposite charge approaches an object, such as the flower. Thus, it can be expected that as a pollinator approaches a flower, it develops an opposite charge to that of the pollinator, potentially causing pollen to be attracted to floral structures and vice versa. Forces due to electrostatics can significantly enhance deposition of pollen on pollinators and on stigmas; thus enhancing the process of pollination.

Although Banerjee and Law demonstrated, under controlled laboratory conditions, the use of a powder charging concept to charge pollen for effective pollination, to date there are no efficient mechanized pollination methods. However, interest in understanding the electric fields surrounding flowers has led to many questions such as: 1) do floral size and shape affect the electrostatic properties of flowers? 2)do electrostatic properties affect the delivery of pollen to, and capture from, pollinators? And 3) do bees sense the electric field surrounding a flower? Vaknin et al. used an experimental approach to study the pollination of model flowers of different sizes and shapes. Their study not only illustrates a new way to analyze floral form and function experimentally, but also demonstrates the potential importance of a largely unrecognized selective force that may significantly influence the evolution of floral form. Moreover, Clarke et al. investigated the use of electric fields by pollinators as informative cues. Their study shows how bees can learn to distinguish between fields produced by different floral shapes, or use them to work out whether a flower has been recently visited by other pollinators. The authors believe that the sensory modality may facilitate rapid and dynamic communication between flowers and their pollinators as floral electric fields can change within seconds. Certainly, the topic "electrostatic pollination" is interesting for ESA members to think upon, as there may be good alternative solutions under the current situation of a declining bee population.

Just a gentle reminder, it is time to plan for your trip to 2017 ESA annual meeting in Ottawa, Canada.

(cont'd. p. 2)

President's Message (cont'd.)

Registration is now open and you can get the benefit by registering before May 10th 2017. Remember you can also pay your membership dues at the same time. Profs. Mehrani and Banerjee have been working hard to put together an excellent technical program, and of course local arrangements, that best comforts everyone. It is expected that presenters from around twelve different countries will participate and give eighty presentations. Looking forward to a great meeting and seeing you in Ottawa.

For the Friendly Society
Shesha Jayaram, *shesha.jayaram@uwaterloo.ca*
President, Electrostatics Society of America

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D. Clarke, H. Whitney, G. Sutton, and D. Robert, "Detection and Learning of Floral Electric Fields by Bumblebees", Science, Vol. 340, April 2013; http://science.sciencemag.org/content/340/6128/66.full

ESA Officers

President:
Shesha Jayaram, Univ. of Waterloo
Vice President and Awards Chair:
Maciej Noras, Univ. of North Carolina
Executive Council:
David Go, Univ. of Notre Dame
Poupak Mehrani, Univ. of Ottawa
Rajeswari Sundararajan, Purdue Univ.

Calendar

- ESA 2017 Annual Meeting, June 13-15, 2017, University of Ottawa, Ottawa, Ontario, Canada *http://www.electrostatics.org* Contact: Poupak Mehrani, *poupak.mehrani@uottawa.ca*
- 2017 Electrical Insulation Conference, June 11-14, 2017, Baltimore, Maryland *http://electricalinsulationconference.com/* Contact: Bill McDermid *wmmcdermid@hydro.mb.ca*
- 2017 IEEE/IAS Annual Meeting, Sept 29- Oct. 5, 2017, Cincinnati, Ohio *http://ias.ieee.org/2017annualmeeting.html* Contact: Maciej Noras *mnoras@uncc.edu*
- 2017 CEIDP, Oct. 22-25, 2017, Fort Worth, Texas Contact: Enis Tuncer *e-tuncer@ti.com*

Book Review - Glenn Schmeig

An Introduction to Lightning
Vernon Cooray, Springer, 2015

Professor Cooray of Uppsala University has written a modern, thorough, detailed account of lightning in 386 pages. The publisher promises a book that "summarizes the essence of physics and effects of lightning in a non-technical manner ... it is also a valuable reference resource for the laymen." How does it do?

Coverage of sub-topics is very broad. Chapters are devoted to electrical characteristics of the atmosphere, charge generation, currents and electromagnetic fields, the lightning return stroke, stepped leaders, lightning damage, and lightning protection. Each chapter concludes with a list of references to research literature. And Cooray is a clear writer. Most descriptive paragraphs are easy to follow, but the math level may surprise.

Would an undergraduate or layman expect the full Maxwell equations in both differential and integral form as early as page 49? Or would they expect examples of retarded potentials and transmission line theory? These topics are usually presented to a much more advanced audience.

I can recommend the book for upper level undergraduates with the help of a competent and patient teacher, but I cannot suggest it to laymen. There is simply too much math. But it could be a good "bridge" book between descriptive books without mathematics and more advanced research monographs. Also, as a first edition, there are many small errors, misprints and repetitious phrases. Hopefully, the second edition will have a careful proofreader.

Some of the easiest and most readable material is near the end. I can particularly praise Chapter 16: "Interaction of Lightning Flashes with Humans". Here, Cooray is at his best with excellent prose and very clear colored diagrams.

There are many short books on lightning that could be your first. If you wish to go on, this should be your second!

Election of ESA Council Members

The ESA Bylaws provide for the election of officers every two years. Members vote for a complete slate of candidates at the annual meeting, and anyone is eligible to nominate or be part of a slate.

At this time, we have one nominated slate of candidates for this years election:

Slate of ESA Officers for 2017-2019
President
Shesha Jayaram, Univ. of Waterloo
Vice President
Maciej Noras, Univ. of North Carolina
Executive Council
David Go, Univ. of Notre Dame
Poupak Mehrani, Univ. of Ottawa
Rajeswari Sundararajan, Purdue Univ.

If anyone would like to nominate an alternate slate, please inform me well before the June conference so that we can prepare election materials for the business meeting.

Absent an alternate slate, we will likely approve the current nominated slate by acclamation.

Shesha Jayaram, ESA President
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ESA Elections By-Laws - New Council Slates Are Sought

Based on Article 4 of the ESA Constitution, the term of the present ESA Council ends on June 30, 2017 and the new Council term of office begins on July 1, 2017. It is now time for the Secretary (address found on back page of this ESA Newsletter) to receive slates of nominees for the upcoming (7/1/17 - 6/30/19) term.

Since the Council shall be nominated as a full slate, the presenter of that slate is responsible for checking with all the members of that slate to insure each nominee is willing to serve. A slate consists of five members: the President, the Vice-President and three Council Members.

If more than one slate is presented to the Secretary, a ballot will be mailed out about May 15 (or as soon as reasonably possible) with the deadline for receipt of the ballots by the Secretary being June 2, 2017. If only one slate is presented (then as tradition has held) no ballots will be mailed, and the Membership present at the ESA Annual Meeting will be asked to vote on the slate. If no slates are presented, then, as Article 4b states, "If extraordinary circumstances prevent the election of a new Council, the existing Council shall continue in office, year by year, until an election can be held."

ESA Award Nominations

The ESA is accepting nominations for the following awards:

The E**SA Distinguished Service Award** recognizes outstanding service to the ESA over an extended period of time, with a demonstrated long-term commitment to the growth and continued well-being of the Society (requirement: 10 years as ESA member).

The **ESA Lifetime Achievement Award** recognizes outstanding contributions to the field of Electrostatics, as shown by the pervasiveness of the contributions in understanding certain problems or important practical benefits resulting from the work (requirement: 10 years working in field of Electrostatics).

The **ESA Honorary Life Member Award** recognizes exceptional contributions to both the ESA and to the field of Electrostatics, sustained over much of a career (requirements: 10 years as ESA member, 20 years working in field of Electrostatics).

The **Teacher of the Year Award** recognizes outstanding teachers who use Electrostatics to stimulate learning, inspire students, or otherwise encourage and energize the learning process in a formal educational setting in grades K-12 (requirement: 3 years teaching Electrostatics).

The **Student of the Year Award** recognizes middle or high school students who demonstrate outstanding achievement in Electrostatics, as showcased in laboratory projects, papers or presentations.

The ESA is also accepting nominations for induction to the Electrostatic Hall of Fame. This honor recognizes and records for posterity those individuals who have made extraordinary contributions to the field of Electrostatics. Nominees do not need to be still living. The Hall of Fame has three categories: (1) advancement of the fundamental knowledge of Electrostatics; (2) promotion of interest in the field of Electrostatics; (3) innovations using Electrostatics technology in industry.

Nominations should be submitted electronically to the ESA Award Chair, Prof. Maciej Noras at *mnoras@uncc.edu*, by May 15. The nomination should be in the form of a letter from an ESA member that includes a description of how the accomplishments of the nominee satisfy the award requirements (including citations of publications or patents when relevant), the contact information of the nominator and nominee, and the names and contact information of 3 other ESA members who endorse the nomination. For the Teacher and Student awards, endorsements from two faculty members of the nominee's should substitute for the ESA member endorsements

Saturn Moon Titan's 'Electric Sand' Would Make Super Castles

Charles Q. Choi

(thanks to M. Murtomaa for this submission)

Electrified sands on Saturn's largest moon, Titan, may stick together due to static cling, potentially meaning that sand castles there would last for weeks, a new study finds. Titan is bigger than the planet Mercury, making it the largest of the more than 60 known moons orbiting Saturn. In certain ways, Titan is reminiscent of Earth; for example, rivers, lakes and oceans cover Titan's surface, though they are made of methane and ethane instead of water.

"At first glance, if you look at images from NASA's Cassini spacecraft, Titan looks very Earth-like, with dunes, lakes, oceans, mountains and potentially volcanoes, and it has a dense, nitrogen-rich atmosphere like Earth's," said study lead author Joshua Méndez, a granular dynamicist at the Georgia Institute of Technology in Atlanta. "But once you start looking at the details, you realize that it is an alien and exciting world." Titan is covered with dunes and plains made of sand consisting of a range of organic molecules. Méndez speculated that the moon's sand might readily become electrically charged, making its behavior significantly different from that of Earth sand.

Méndez's specialty is electrified particles. He investigates phenomena such as volcanic lightning, which is powered by electrically charged volcanic ash particles, and studies "powders in the pharmaceutical industry, which can clump together or stick to the walls of pipes because of their electric charge," he said. "It turns out that sand grains on Titan are not so different from pharmaceutical particles," Méndez told Space.com. "So I wanted to see how such particles might act on Titan."

Sand grains and other particles can build up electric charge through the "triboelectric effect," the same effect behind everyday static electricity. When two different materials repeatedly collide with or rub against one another, the surface of one material can steal electrons from the surface of the other, accumulating charge.

The strength of Earth's gravitational pull typically overwhelms any effect that triboelectricity might have on shaping the planet's dunes, Méndez said. However, Titan's surface gravity is more than seven times weaker than Earth's, meaning that triboelectricity might play a more conspicuous role on that moon, he said. In addition, while sand grains on Earth are often made of silicate minerals, the organic sand grains of Titan are typically fluffier, and this lighter nature could make them easier to push around, Méndez said.

Moreover, the atmospheric pressure on Titan is greater than that on Earth, while its air is dry and cold, and its sands are typically made of electrically insulating materials. All these factors should help sand on Titan hold onto electric charge longer than on Earth, the researchers said.

The researchers explored how windblown sand might behave on Titan by experimenting with particles made with naphthalene and biphenyl, two mildly toxic organic compounds that previous research suggested might exist on Titan's surface. The scientists rotated a small tube holding these particles for 20 minutes in a dry, pure-nitrogen environment. (Titan's atmosphere is about 98 percent nitrogen.)

Results showed that all the particles accumulated electric charge, with about 2 percent to 5 percent sticking onto the tumbler's walls. "When we did the same

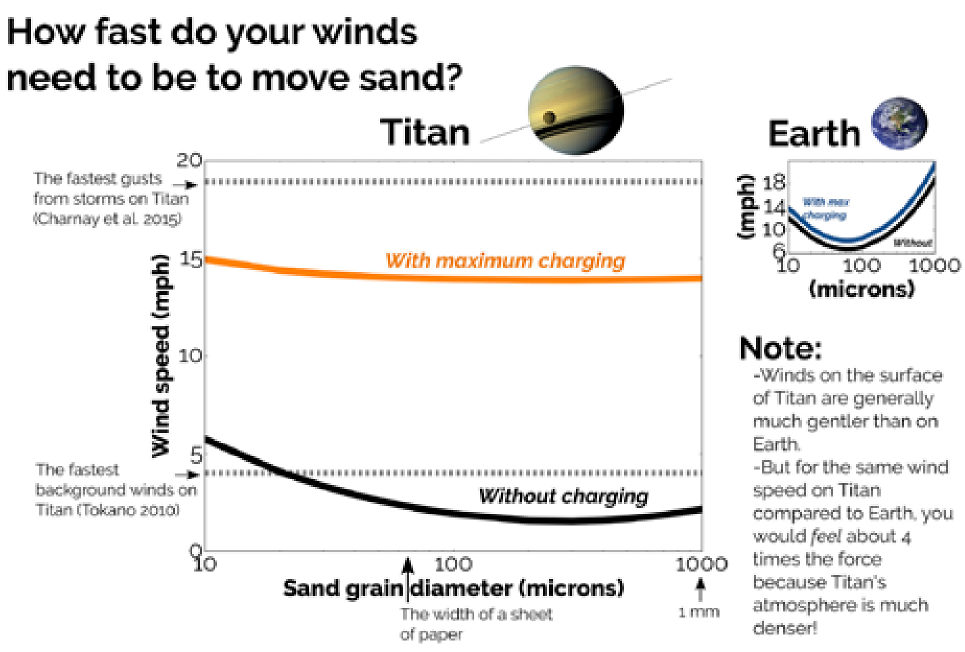
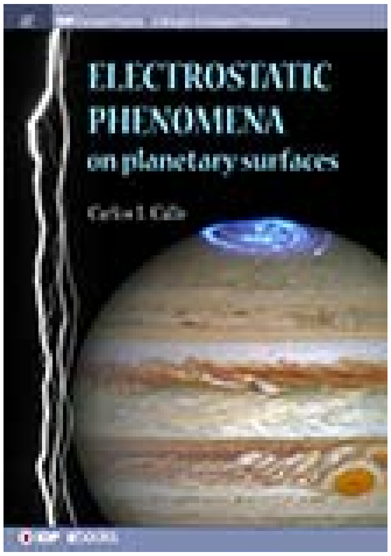


Image Credit: G.D. McDonald, J.S. Méndez Harper, NASA, JPL-Caltech, SSI

Book Announcement

Electrostatic Phenomena on Planetary Surfaces

Carlos I. Calle



The diverse planetary environments in the solar system react in somewhat different ways to the encompassing influence of the sun. These different interactions define the electrostatic phenomena that take place on and near planetary surfaces. The desire to understand the electrostatic environments of planetary surfaces goes beyond scientific inquiry. These environments have enormous implications for both human and robotic exploration of the solar system.

This book describes in some detail what is known about the electrostatic environment of the solar system from early and current experiments on Earth as well as what is being learned from the instrumentation on the space exploration missions (NASA, European Space Agency, and the Japanese Space Agency) of the last few decades. It begins with a brief review of the basic principles of electrostatics.

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Current Events (cont'd.)

experiment with sand and volcanic ash using Earth-like conditions, all of it came out. Nothing stuck," Méndez said in a statement.

All in all, "if you grabbed piles of grains and built a sand castle on Titan, it would perhaps stay together for weeks due to their electrostatic properties," study co-author Josef Dufek, at the Georgia Institute of Technology, said in a statement. Whereas sand castles on Earth typically need water to stick together, these structures on Titan could rely somewhat on electric charge, which the sand there could retain for up to months, the researchers said. "Our findings highlight that caution is needed when applying models from Earth to other environments," Méndez said. "We have to rethink our assumptions with a world as different as Titan."

These findings might help explain an odd phenomenon, the researchers said. Prevailing winds on Titan blow from east to west across the moon's surface, but sandy dunes nearly 300 feet (90 meters) tall seem to form in the opposite direction. Titan's sand grains may be "so sticky and cohesive that only heavy winds can move them," Méndez said in a statement. "The prevailing winds aren't strong enough to shape the dunes."

Méndez said he did not think this sticky sand would pose insurmountable challenges for missions dispatched to Titan's surface. "When missions landed on Mars and the moon, they had to deal with dust sticking to everything, too," Méndez said. "Maybe whatever robots we send to Titan will have to be able to clean themselves."

In the future, the researchers would like to carry out larger-scale experiments to see if electricity might indeed help create big structures on Titan, Méndez said.

(excerpted from *http://www.space.com/36472-saturn-moon-titan-electric-sand.html*)

NASA Study Finds Solar Storms Could Spark Soils at Moon's Poles

Robert Emmerich

Powerful solar storms can charge up the soil in frigid, permanently shadowed regions near the lunar poles, and may possibly produce "sparks" that could vaporize and melt the soil, perhaps as much as meteoroid impacts, according to NASA-funded research. This alteration may become evident when analyzing future samples from these regions that could hold the key to understanding the history of the moon and solar system.

The moon has almost no atmosphere, so its surface is exposed to the harsh space environment. Impacts from small meteoroids constantly churn or "garden" the top layer of the dust and rock, called regolith, on the moon. "About 10 percent of this gardened layer has been melted or vaporized by meteoroid impacts," said Andrew Jordan of the University of New Hampshire, Durham. "We found that in the moon's permanently shadowed regions, sparks from solar storms could melt or vaporize a similar percentage." Jordan is lead author of a paper on this research published online in Icarus August 31, 2016.

Explosive solar activity, like flares and coronal mass ejections, blasts highly energetic, electrically charged particles into space. Earth's atmosphere shields us from most of this radiation, but on the moon, these particles -- ions and electrons -- slam directly into the surface. They accumulate in two layers beneath the surface; the bulky ions can't penetrate deeply because they are more likely to hit atoms in the regolith, so they form a layer closer to the surface while the tiny electrons slip through and form a deeper layer. The ions have positive charge while the electrons carry negative charge. Since opposite charges attract, normally these charges flow towards each other and balance out.

In August 2014, however, Jordan's team published simulation results predicting that strong solar storms would cause the regolith in the moon's permanently shadowed regions (PSRs) to accumulate charge in these two layers until explosively released, like a miniature lightning

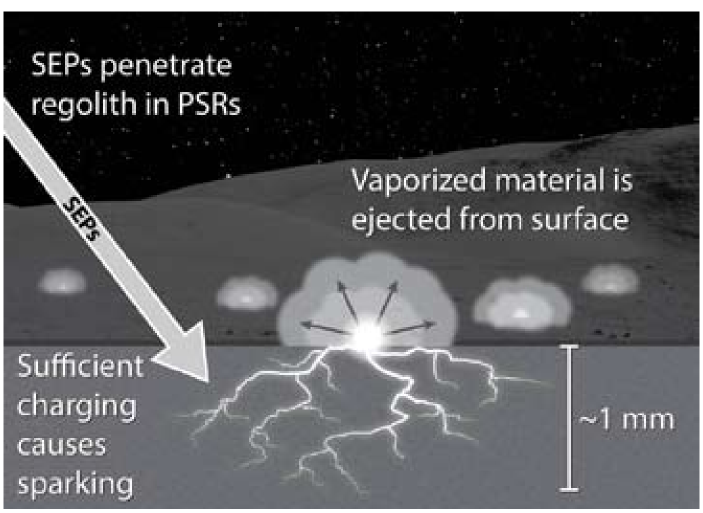


Illustration showing how solar energetic particles may cause dielectric breakdown in lunar regolith in a permanently shadowed region (PSR). Tiny breakdown events could occur throughout the floor of the PSR. Credits: NASA/Andrew Jordan

strike. The PSRs are so frigid that regolith becomes an extremely poor conductor of electricity. Therefore, during intense solar storms, the regolith is expected to dissipate the build-up of charge too slowly to avoid the destructive effects of a sudden electric discharge, called dielectric breakdown. The research estimates the extent that this process can alter the regolith.

"This process isn't completely new to space science -- electrostatic discharges can occur in any poorly conducting (dielectric) material exposed to intense space radiation, and is actually the leading cause of spacecraft anomalies," said Timothy Stubbs of NASA's Goddard Space Flight Center in Greenbelt, Maryland, a co-author of the paper. The team's analysis was based on this experience. From spacecraft studies and analysis of samples from NASA's Apollo lunar missions, the researchers knew how often large solar storms occur. From previous lunar research, they estimated that the top millimeter of regolith would be buried by meteoroid impacts after about a million years, so it would be too deep to be subject to electric charging during solar storms. Then they estimated the energy that would be deposited over a million years by both meteoroid impacts and dielectric breakdown driven by solar storms, and found that each process releases enough energy to alter the regolith by a similar amount.

"Lab experiments show that dielectric breakdown is an explosive process on a tiny scale," said Jordan. "During breakdown, channels could be melted and vaporized through the grains of soil. Some of the grains may even be blown apart by the tiny explosion. The PSRs are important locations on the moon, because they contain clues to the moon's history, such as the role that easily vaporized material like water has played. But to decipher that history, we need to know in what ways PSRs are not pristine; that is, how they have been weathered by the space environment, including solar storms and meteoroid impacts."

The next step is to search for evidence of dielectric breakdown in PSRs and determine if it could happen in other areas on the moon. Observations from NASA's Lunar Reconnaissance Orbiter spacecraft indicate that the soil in PSRs is more porous or "fluffy" than other areas, which might be expected if breakdown was blasting apart some of the soil grains there. However, experiments, some already underway, are needed to confirm that breakdown is responsible for this. Also, the lunar night is long -- about two weeks -- so it can become cold enough for breakdown to occur in other areas on the moon, according to the team. There may even be "sparked" material in the Apollo samples, but the difficulty would be determining if this material was altered by breakdown or a meteoroid impact. The team is working with scientists at the Johns Hopkins University Applied Physics Laboratory on experiments to see how breakdown affects the regolith and to look for any tell-tale signatures that could distinguish it from the effects of meteoroid impacts..

(from *https://solarsystem.nasa.gov/news/2017/01/08/nasa-study-finds-solar-storms-could-spark-soils-at-moons-poles*)

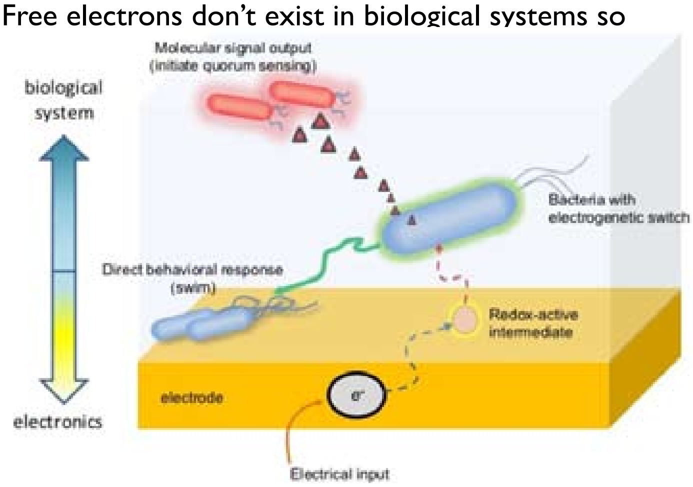
Using electricity, not molecules, to switch cells on and off

William Bentley and Gregory Payne

One of the barriers scientists have encountered when trying to link microelectronic devices with biological systems has to do with information flow. In biology, almost all activity is made possible by the transfer of molecules like glucose, epinephrine, cholesterol and insulin signaling between cells and tissues. Infecting bacteria secrete molecular toxins and attach to our skin using molecular receptors. To treat an infection, we need to detect these molecules to identify the bacteria, discern their activities and determine how to best respond.

Microelectronic devices don't process information with molecules. A microelectronic device typically has silicon, gold, chemicals like boron or phosphorus and an energy source that provides electrons. By themselves, they're poorly suited to engage in molecular communication with living cells.

Free electrons don't exist in biological systems so



Bacteria are engineered to respond to a redox molecule activated by an electrode by creating an electrogenetic switch. Bentley and Payne, CC BY-ND

there's almost no way to connect with microelectronics. There is, however, a small class of molecules that stably shuttle electrons. These are called "redox" molecules; they can transport electrons, sort of like wire does. The difference is that in wire, the electrons can flow freely to any location within; redox molecules must undergo chemical reactions – oxidation or reduction reactions – to "hand off" electrons.

Capitalizing on the electronic nature of redox molecules, we genetically engineered bacteria to respond to them. We focused on redox molecules that could be "programmed" by the electrode of a microelectronic device. The device toggles the molecule's oxidation state – it's either oxidized (loses an electron) or reduced (gains an electron). The electron is supplied by a typical energy source in electronics like a battery.

We wanted our bacteria cells to turn "on" and "off" due to the applied voltage – voltage that oxidized a naturally occurring redox molecule, pyocyanin. Electrically oxidizing pyocyanin allowed us to control our engineered cells, turning them on or off so they would synthesize (or not) a fluorescent protein. We could rapidly identify what was happening in these cells because the protein emits a green hue.

In another example, we made bacteria that, when switched on, would swim from a stationary position. Bacteria normally swim in starts and stops referred to as a "run" or a "tumble." The "run" ensures they move in a straight path. When they "tumble," they essentially remain in a one spot. A protein called CheZ controls the "run" portion of bacteria's swimming activity. Our electrogenetic switch turned on the synthesis of CheZ, so that the bacteria could move forward.

We were also able to electrically signal a community of cells to exhibit collective behavior. We made cells with switches controlling the synthesis of a signaling molecule that diffuses to neighboring cells and, in turn, causes changes in their behavior. Electric current turned on cells that, in turn, "programmed" a natural biological signaling process to alter the behavior of nearby cells. We exploited bacterial quorum sensing – a natural process where bacterial cells "talk" to their neighbors and the collection of cells can behave in ways that benefit the entire community.

Perhaps even more interesting, our groups showed that we could both turn on gene expression and turn it off. By reversing the polarity on the electrode, the oxidized pyocyanin becomes reduced – its inactive form. Then, the cells that were turned on were engineered to quickly revert back to their original state. In this way, the group demonstrated the ability to cycle the electrically programmed behavior on and off, repeatedly.

Interestingly, the on and off switch enabled by pyocyanin was fairly weak. By including another redox molecule, ferricyanide, we found a way to amplify the entire system so that the gene expression was very strong, again on and off. The entire system was robust, repeatable and didn't negatively affect the cells. Armed with this advance, devices could potentially electrically stimulate bacteria to make therapeutics and deliver them to a site. For example, imagine swallowing a small microelectronic capsule that could record the presence of a pathogen in your GI tract and also contain living bacterial factories that could make an antimicrobial or other therapy – all in a programmable autonomous system.

This current research ties into previous work done here at the University of Maryland where researchers had discovered ways to "record" biological information, by sensing the biological environment, and based on the prevailing conditions, "write" electrons to devices. We and our colleagues "sent out" redox molecules from electrodes, let those molecules interact with the microenvironment near the electrode and then drew them back to the electrode so they could inform the device on what they'd seen. This mode of "molecular communication" is somewhat analogous to sonar, where redox molecules are used instead of sound waves.

These molecular communication efforts were used to identify pathogens, monitor the "stress" in blood levels of individuals with schizophrenia and even determine the differences in melanin from people with red hair. For nearly a decade, the Maryland team has developed methodologies to exploit redox molecules to interrogate biology by directly writing the information to devices with electrochemistry.

(excerpted from *http://theconversation.com/using-electricity-not-molecules-to-switch-cells-on-and-off-71306*)

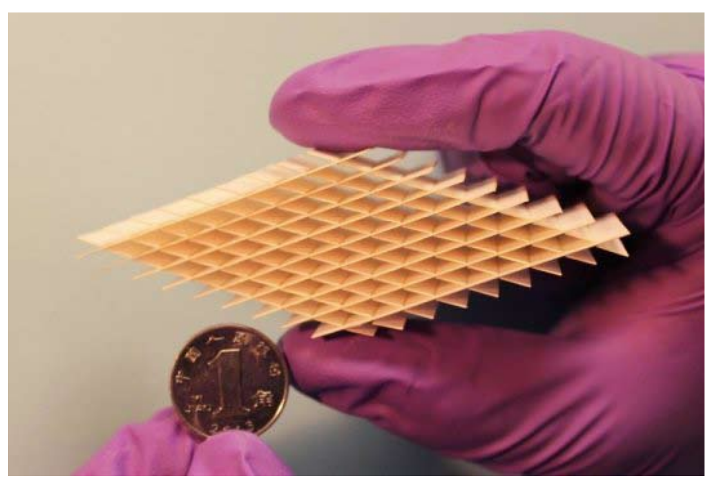
Art of paper-cutting inspires self-charging paper device

Despite the many advances in portable electronic devices, one thing remains constant: the need to plug them into a wall socket to recharge. Now researchers, reporting in the journal ACS Nano, have developed a light-weight, paper-based device inspired by the Chinese and Japanese arts of paper-cutting that can harvest and store energy from body movements.

Portable electronic devices, such as watches, hearing aids and heart monitors, often require only a little energy. They usually get that power from conventional rechargeable batteries. But Zhong Lin Wang, Chenguo Hu and colleagues wanted to see if they could untether our small energy needs from the wall socket by harvesting energy from a user's body movements. Wang and others have been working on this approach in recent years, creating triboelectric nanogenerators (TENGs) that can harness the mechanical energy all around us, such as that created by our footsteps, and then use it to power portable electronics. But most TENG devices take several hours to charge small electronics, such as a sensor, and they're made of acrylic, which is heavy.

So the researchers turned to an ultra-light, rhombic paper-cut design a few inches long and covered it with different materials to turn it into a power unit. The four outer sides, made of gold- and graphite-coated sand paper, comprised the device's energy-storing supercapacitor element. The inner surfaces, made of paper and coated in gold and a fluorinated ethylene propylene film, comprised the TENG energy harvester. Pressing and releasing it over just a few minutes charged the device to 1 volt, which was enough to power a remote control, temperature sensor or a watch.

(from *https://www.sciencedaily.com/releases/2017/04/170412091118.htm*)



Researchers have developed a paper-based device inspired by the Chinese and Japanese arts of paper-cutting that can harvest and store energy from body movements.
Credit: American Chemical Society

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ESA 2017 Annual Meeting
June 13-15, 2017
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